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6. SUMMARY AND RECOMMENDATIONS

The January 13, 2001 Off the Coast of El Salvador Earthquake

A week after the earthquake, the number of residents evacuated from the zones exposed to the menace of possible landslides reached 14,000, and as of Feb. 3, about 4,000 refugees were still being forced to live in tents (Nueva San Salvador).

6. SUMMARY AND RECOMMENDATIONS

The January 13th, 2001 Earthquake proved the high seismic vulnerability of adobe and bahareque structures in El Salvador. Large RC buildings and most engineered structures appeared to be only lightly damaged. The observed damage included out-of-plane wall collapse, separation of adjacent walls, mud cover spalling, diagonal cracking, vertical cracking of spandrels over the window or door openings, etc. It is however noted that some wooden roof frames put around the top ends of adobe walls were keeping the walls in position. This fact suggests that there are technical solutions available to deal with this problem. People directly involved in the construction of these structures, frequently the owners themselves, are not always aware of those techniques or do not appreciate the importance of their implementation. Thus, one of the current main issues will be to increase the consciousness among the population of the importance of earthquake preparedness.

Earthquake-induced landslides were scattered throughout the region. Especially in areas of volcanic tephra deposits the landslides are often big and numerous. A large amount of soil mass (about 200,000 m^3) was thrown off the rim of a mountain ridge rising south behind Las Colinas area of Nueva San Salvador. This amount of soil is not surprisingly large as contrasted with the huge soil mass of a couple of tens million m^3, which was initiated at the top of the Mt. Huascaran (6,700m EL), and ran about 4 km down to Yungay town killing more than 20,000 people (1970 Peru Earthquake). The Las Colinas landslide, however, was substantially large in terms of damage because the slid soil mass surged across a residential district of Las Colinas, and destroyed many houses and thus causing more than 500 deaths. As for extremely large slope failures, it is very difficult to stop them. It is therefore strongly recommended to develop and enforce land-use building ordinances that regulate constructions in areas susceptible to landslides and debris flows. For this, it is necessary to study basic features of such volcanic products as pumice and tuff. The ring shear test of the water-saturated pumice soil in Section **2.6** shows clearly that the apparent friction angle can drop down even to a few degrees after slipping some distance. This indicates that the soil deposit is particularly susceptible to landslides during intense rainfall. This information will allow us not only to simulate the possible travel distance and the velocity of a soil mass, but also to set up an alarm system. “Trainers Training Program” will be also effective. If your local officers are familiar with the land around you, you will be able to catch an early sign of a landslide.

It is noted in this earthquake that not only the intense shake but also landslides were responsible for the damage to lifelines. It is thus recommended to avoid constructions of some important lifeline facilities on the edges of unstable slopes. At Las Colinas, The topographic effects of ridge apparently had pronounced effect of increasing the strength of the shaking intensity. If unavoidable, constructions should involve some necessary slope stabilizations. Furthermore, making important systems redundant will enhance their robustness.

Putting together all the members findings, it is noted that one of the most spectacular aspects featuring heavily this earthquake was the damage directly or indirectly inflicted by landslides in areas of volcanic tephra deposits. Both El Salvador and Japan are included in the Pacific Ring of Fire, and thus this kind of landslides is a serious threat in both countries. A magnitude 6.8 earthquake struck about 1.1 km beneath Volcano Ontake, Japan, after several days of heavy rain in 1984, and the earthquake triggered a huge landslide with a volume of 32-36 million m^3 on the volcano’s slope. All the members of JSCE reconnaissance team thus wish to further collaborate with Salvadorian experts for possible remedial measures, e.g., reconstruction of damaged structures, retrofitting of existing structures and reducing landslide hazards.

Lastly, all the team members would like to express hereby their sincere sympathy to the people affected by the two devastating earthquakes in El Salvador.

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