General Report —Session IX: Geotechnical Analysis of Recent Earthquakes

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INTRODUCTION

The papers in this session illustrate the range of knowledge that can be gained from postearthquake investigations. The goal of postearthquake investigations is to document, understand, and explain what happened in each damaging earthquake in order to reduce losses from future earthquakes. To achieve this goal, investigations are designed to study parameters of the three interrelated systems which together represent the full range of society's coping capacity and exposure to earthquakes. The individual systems are:

1. the solid earth system, which generates the earthquake ground shaking and geotechnical phenomena that threaten the built environment of the community,

2. the built environment system, which houses, services and sustains people and property in the community exposed to the potentially destructive impacts of earthquake phenomena, and

3. the social-economic-political system of a community, which calls for the adoption and enforcement of earthquake risk management policies and practices that will enable the community to withstand and recover from a destructive earthquake.

The physical phenomena (of an earthquake) damage or destroy buildings and lifeline systems (e.g., bridges, dams, pipelines, utility systems, tunnels, rapid transit) in urban centers and cause socioeconomic impacts over broad geographic regions. Within a minute or less ground shaking and geotechnical effects can trigger economic losses which can reach several tens of billions of dollars. Ground shaking can trigger liquefaction (i.e., a temporary loss of bearing strength at locations underlain by young, loosely compacted, water-saturated sand deposits) and landslides (i.e., falls, topples, slides, spreads, and flows of rock and/or soil on unstable slopes) which can disrupt and destroy infrastructure, agriculture, and natural resources. Some earthquakes will also generate surface fault rupture where, depending on the magnitude or amount of mechanical energy released at the initial rupture zone, the fault can propagate upward, and break the surface. Surface fault rupture, liquefaction, and landsliding cause permanent displacements, which can be especially damaging to underground lifeline systems. Regional tectonic deformation (i.e., changes in elevation over a broad geographic region) is a characteristic of great-magnitude earthquakes (i.e., those having magnitudes of 8 or greater). Tsunamis (i.e., long-period ocean waves generated by the sudden vertical displacement of a submarine earthquake) can generate flood waves that can destroy ports and harbors and buildings at coastal locations far from and close to the earthquake source. Seiches (standing waves induced in lakes and harbors), dam failures, and fires can also be induced by an earthquake. Aftershocks (i.e., smaller magnitude earthquakes, following the main shock) can occur over a period of several months to years, repeating and worsening the physical effects described above, depending on their magnitude, proximity to the urban center building or lifeline or site, and the incipient damage state of the remaining structures. The knowledge gained from investigations provides a basis for determining the best ways to prevent future losses and insight on how to implement them.

HIGHLIGHTS OF PAPERS

The papers in this session contain valuable information on geologic, geophysical, and geotechnical analyses of past earthquakes. Some of the principal findings are presented below.

Nowroozi (Paper 9.02) analyzed the spatial distribution of epicenters of past earthquakes in the low seismicity regime of the Southeastern United States and was able to correlate the predominant directions of seismic lineaments with the dominant stress direction. This analysis showed that sliding on a weak fracture plane can occur for a wide range of angles between the sliding plane and the principal stress axes, depending on mean stresses, cohesive shear strengths, and rock frictional angles.

Athanasopoulos (Paper 9.04) analyzed the ground response in Patras, a coastal city in seismically active Southern Greece, using the finite element program LUSH 2, in-situ and laboratory geotechnical data, and two representative earthquake time histories. On the basis of these results, peak ground accelerations and spectral accelerations are expected to vary by a factor of about 5 throughout the city. This study suggests the feasibility and value of seismic zonation as a basis for improving policies and practices in Patras to reduce the risk.

Lazarte and Bray (Paper 9.10) presented observations and models on the effects of surface fault rupture on soil deposits. Their research shows that the width of the shear zone of strike-slip faulting depends on the ductility and height of the soil deposit.

Tani (Paper 9.15) studied the 1993 Kushrio-oki and Hokkaido-Nansei-oki earthquakes. These two M 7.8 earthquakes caused extensive damage to farm roads, irrigation and drainage canals.

Maurenbrecher, Outer, and Luger (Paper 9.16) used postearthquake investigations of the M 5.8 April 13, 1992, Roermond earthquake near the Dutch-German border to evaluate the predictions of soil liquefaction made in 1987 solely on the basis of geotechnical analyses. This study provided a deeper understanding of the strengths and weaknesses of models of liquefaction and called for new research and improved professional practices.

Maugeri and Frenna (Paper 9.17) investigated the effects of the M 5.4 December 13, 1994 Southeast Sicily earthquake in Augusta and Lentini, two locations experiencing extensive damage in the moderate earthquake. Using field and laboratory geotechnical tests and a 1-D analytical model, they showed that the damage was strongly correlated with the old "salt ponds" which amplified the ground motion in selected period bands favorable for soil-structure resonance.

TOPICS FOR FURTHER DIALOGUE

These papers provide a basis for dialogue on a number of important topics. They include:

1. Organizing and implementing successful geotechnical studies within a comprehensive program of postearthquake investigations.

2. Uncertainties and differences in the results of laboratory and field geotechnical studies and constraints they place on siting, design, and construction practices.

3. Soil amplifications and liquefaction effects (ranges and uncertainties) expected in low-to-moderate-seismicity regimes and different geotechnical environments.

4. Technical and political feasibility of seismic zonation to identify those parts of a geographic area that are prone to enhanced soil amplification or soil liquefaction.

REFERENCE

United States Geological Survey, 1993, The National Earthquake Hazards Reduction Program of Postearthquake Investigations, Geological Survey Open-File Report 93-528, Reston, VA, 14 p.