SOCIAL SEISMOLOGY : THE EARTHQUAKE RISK MANAGEMENT PROJECT IN QUITO, ECUADOR

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Introduction

The worldwide threat from earthquakes is growing : in 1900, one of every three large earthquakes killed humans, while today nearly two out of three are fatal. Earthquakes are not more frequent nor more powerful, rather, the number and size of vulnerable cities is growing. The world's urban population is dramatically increasing : from about 30% of the world's population in 1950 it is expected to reach roughly 50% by 2000. This growth is absorbed by cities becoming larger and more vulnerable : in 1950, only 25% of the world's 50 largest cities were located within 200 kilometers of an historical magnitude 7 earthquake compared to about 50% in the year 2000.

As countries become more developed, earthquakes cause fewer deaths and greater economic losses : the 1987 Loma Prieta earthquake (USA) caused 62 deaths and $4.7 billion of economic losses in and around San Fransisco, while a similar sized earthquake in Spitak (Armenia) killed over 20000 people and $570 million of economic losses. The economic loss in Spitak represented 95% of Armenia's GNP, while the loss from the Loma Prieta Earthquake represented only 0.2% of the United States GNP.

The Quito earthquake risk management project is a pilot project in social seismology launched in a developing country. Its purpose was to provide direction to government officials, business leaders, and the public in general, to reduce damage and injury in the next major earthquake. The scientific work involved institutions from Ecuador, Canada, France, Japan and the United States, in the fields of seismology, geology, soil mechanics, structural engineering, and city planning.

The project was divided into three phases. In the first, damaging earthquakes and their effects on Quito were analyzed. In the second, the impact on life in Quito during the month following one of these earthquakes was described in vivid, non technical terms. Finally, based on the first two

indicates that it has the potential for generating a larger magnitude earthquake. This earthquake is also modeling the 1587 earthquake located, possibly, on an active North-South trending fault.
At the same time, twenty-three earthquakes that produced intensities of VI or greater during Ecuador's 460 years of written history, which includes 1104 seismic intensity observations, were used to establish attenuation relations for the country, which were then corrected for application to the city of Quito.

2.- Division of the city into seismic zones : soil characteristics were obtained from over 2,000 drillings from various sources (e.g., private consultants, municipality files, and EPN studies). Based on topography, soil characteristics, and surface geology the city has been divided into 20 zones. For each of these zones a representative soil column was established down to a depth of 20 meters, usually not reaching the base rock, whose depth is unknown.

3.- Evaluation of the intensity distribution in the city based on these zone to prepare seismic intensity distribution (SID) maps for each of the three chosen earthquakes. Intensities in the 20 zones were computed using soil models and seismic responses, peak accelerations and soil amplifications, for the 3 hypothetical earthquakes, leading to the following results intensity ranges : subduction earthquake : 5.6 - 6.1 ; inland earthquake : 6.1 - 6.9 ; local earthquake : 6.3 - 8.0
These results were checked by comparing the computed intensity with observed intensities for the 1987 event.

4.- Evaluation of the location and distribution of different structural types (buildings, houses) throughout the city. Fifteen main types of structures were identified in Quito. Among those, each of the 9 most common types of buildings were subdivided in three categories, according to building heights. Then, each city block has been classified according to its predominant structural system, i.e. the structural type that covered the greatest area of the block.
In order to estimate the structural vulnerability of the structures, some buildings that we considered as representative of each type of structures were evaluated individually. Special structures such as hospitals, schools, industrial facilities, as well as the sewage system, water reservoir tanks, transmission towers, gas and oil stations near the city, and the airport were inspected individually with more scrutiny.

5.- Evaluation of the consequences of the intensity distribution on the buildings and city services. Physical damage caused by ground shaking was estimated using a relationship between the damage factor versus Modified Mercalli Intensity scale. In the method used, the damage factor is defined as the ratio of the estimated cost due to earthquake damages divided by the facility replacement value. We considered 7 states of damages : none, slight, light, moderate, heavy, major, destroyed. Finally, the time of recovery for lifelines was estimated. The method has been tested by comparing computed damages to observed damages for the 1987 earthquake.

Second Phase : a month in Quito following a future earthquake.

The scientific analysis of this project, while providing detailed estimates of damage from potential earthquakes, does not communicate the impact of such disasters. The purpose of the second phase of the project was to describe life in Quito during the month following the local earthquake, in order to help government officials, emergency service planners, business leaders and the general public to visualize the consequences of a future major earthquake, and provide the motivation and understanding required to act. The scenario is based on the scientific analysis of the local earthquake and a vulnerability study of Quito's city services, public buildings, and infrastructure.
The vulnerability study was performed by interviewing officials from 17 different city organizations, including sewer, water, power and transportation departments, Civil Defense, and fire and police departments. In a multi-stage process, the interviews were written up and returned to the interviewees