Earthquake Loss Estimates Applied in Real Time and to Megacity Risk Assessment

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ABSTRACT

Real time loss estimates within one to two hours after major earthquakes are becoming useful for disaster managers and rescue teams to respond rapidly and at an optimal level. Tests show that the accuracy is low, but major disasters can be reliably distinguished from inconsequential earthquakes. Many technical and organizational aspects of these estimates can and should be improved. An analysis of what magnitude of disaster is likely to occur, if a major earthquake should occur near a megacity in a developing country shows that much work needs to be done to mitigate the risk, and that the global community is ill prepared to deal with such large disasters.

Keywords

Earthquake risk, earthquake loss estimates, building stock from satellite images, international rescue.

INTRODUCTION

There is need for loss estimates immediately after earthquakes because injured people trapped in collapsed buildings can only be rescued during the first hours to days. In disastrous earthquakes, usually no information flows from the area worst affected, for some time. The information that reaches decision makers at first comes from the edges of the destruction and is therefore an underestimate of the losses. Loss estimates based on modeling earthquake effects are becoming increasingly reliable. The steps needed for these calculations are the following. (1) Obtain hypocenter and magnitude parameters with accuracies of less than 20 km and 0.3 units of magnitude, respectively. (2) Calculate the strong ground motion as a function of distance from the epicenter. (3) Estimate the impact on the building stock by the local ground motion. (4) Calculate the probable effect on people of collapsing and damaged buildings.

In developing countries, the properties of the building stock, fragility curves and distribution of building classes, is poorly known. In addition, the numbers of buildings in these countries are too large for engineers to inspect and classify the buildings on the ground. Therefore, 3D models of cities, derived from satellite images, can greatly help in improving the approximate knowledge of the properties of the building stock.

This paper briefly describes the state-of-the-art in real time loss assessment after earthquakes, based on modeling the strong ground motion effects, and it describes what order of magnitude disasters due to earthquakes in the vicinity of megacities in the developing world may have.

REAL TIME LOSS ESTIMATES AFTER EARTHQUAKES

Real time loss estimates after major earthquakes are beginning to be implemented by several groups. Although the principles of how to calculate these estimates are understood, there remain many aspects that need to be refined, and data sets need to be improved. The Russian Ministry of Civil Defense, Emergencies, and the Elimination of the Consequences of Natural Disasters (EMERCOM) maintains a Web site (www.ampe.ru/english/progn/seism/conseq.shtml) on which loss estimates of earthquakes since June 2001 are listed {Shakhramanjyan, 2001 #1886}. The U.S. Geological Survey (USGS) has launched the Prompt Assessment of Global Earthquakes for Response (PAGER) system, which aims to go beyond the Survey's current distribution of earthquake source parameters by adding estimates of the expected losses in real time, worldwide. In August 2004, USGS sponsored a workshop in Golden, Colorado to assist with defining the scope and methods to be used in PAGER {Earle, 2003 #2000}. The Joint Research Center of the European Commission displays on its Web site (dma.jrc.it) the population numbers within the vicinity of epicenters in real time, and distributes alerts by e-mail (T. de Groeve, personal communication, 2003). The most extensive, published record of real-time loss estimates is that of the computer tool QUAKELOSS {Wyss , 2004 #1994}. For 100 earthquakes with a pre-defined threshold magnitude, loss estimates were distributed by e-mail to about a dozen interested agencies and individuals in real time during the period November 2002– December 2004.

The problem of real-time loss estimates after earthquakes falls into two categories with different approaches: one for highly developed and one for developing countries. Errors in earthquake parameters are an order of magnitude larger, they become available an order of magnitude later, and the details of the conditions of the built environment are not known in developing countries. Nevertheless, it has been possible during the last two years to deliver to rescue agencies reliable loss estimates within approximately two hours of major earthquakes. If we define as 'correct' an estimate that allows rescue agencies to make the right decision to mobilize or not, then over 90% of inconsequential earthquakes can be defined, and over 70% of disastrous ones can be recognized in real-time. This result is based on 100 real time alerts, distributed to about a dozen agencies and individuals {Wyss , 2004 #1994}.

WAPMERR is currently offering a service of loss estimates for earthquakes with M ≥ 6 anywhere in the world, to anyone who wishes to subscribe. The service includes (1) an estimate of the number of casualties sent by email, (2) a telephone call with discussion of the estimate and its error limits, if desired, and (3) a password-protected web site with a map showing the calculated average destruction in all settlements affected, as well as a list of those settlements.

Technical areas that need to be improved include the following. (1) The uncertainty in teleseismic depth estimates for shallow earthquakes leads to unstable solutions in some cases and needs to be replaced by an "expert depth." (2) The source of energy radiated should be modeled as an extended rupture for large earthquakes, rather than as a point. (3) Regional attenuation functions for seismic waves should be implemented in calculating strong ground motions. (4) Information on microzonation of soil properties in cities should be used, where available.

EARTHQUAKE RISK IN MEGACITIES OF DEVELOPING COUNTRIES

Defining casualties as the sum of the fatalities plus injured, we use their mean number, as calculated by QUAKELOSS (developed by Extreme Situations Research Center, Moscow) as a measure of the extent of possible disasters due to earthquakes. Examples of cities we examined include Algiers, Cairo, Istanbul, Mumbai and Teheran, with populations ranging from about 3 to 20 million. With the assumption that the properties of the building stock has not changed since 1950, we find that the number of expected casualties will have increased about 5 to 10 fold by the year 2015. This increase is directly proportional to the increase in population.

For the assumed magnitude, we used M7 and M6.5 because shallow earthquakes in this range can occur in the seismogenic layer, without rupturing the surface. This means, they could occur anywhere in a seismically active area, not only along known faults. As a function of epicentral distance, the fraction of casualties of the population decrease from about 6% at 20 km, to 3% at 30 km and 0.5% at 50 km, for an earthquake of M7. At 30 km distance, the assumed variation of the properties of the building stock from country to country gives rise to variations of 1% to 5% for the estimate of the percent of the population that become casualties.

As a function of earthquake size, the expected number of casualties drops by approximately an order of magnitude for an M6.5, compared to an M7, at 30 km distance. Because the computer code and database in QUAKELOSS are calibrated based on about 1000 earthquakes with fatalities, and verified by real-time loss estimates for about 100 cases, these results are probably of the correct order of magnitude. However, the results should not be taken as overly reliable, because (1) the probability calculations of the losses result in uncertainties of about a factor of two, (2) the method has been tested for medium size cities, not for megacities, and (3) many assumptions were made. Nevertheless, it is clear that there are no hospital facilities anywhere that could take care of the heavily injured (about 1/4 of the total casualties) in any of the scenarios. Given the enormous numbers of casualties that must be expected, even mitigation measures that could only save a fraction of the casualties would help large numbers of people.

NEW APPROACHES TO ELIMINATE PROBLEMS WITH EARTHQUAKE LOSS ESTIMATES

(A) A top priority is the elimination of the "last mile" failure of communication {Wyss , 2004 #1998}. The most serious impediment for rapid rescue deployment is the lack of local experience with, and trust in, international real-time loss estimates. Local civil protection officials too often refuse early offers of assistance from international rescue teams, because the officials underestimate the extent of the disaster. Unfortunately, these decisions are often based on reports of limited damage coming from the edges of the devastated area, where communication still functions. At the same time communication from the strongly affected area may be interrupted, making it temporarily impossible to obtain any information from the most important locations. Meanwhile, international experts may have correctly estimated the losses as high.

These frequent initial underestimates of the extent of earthquake disasters lead to delays in rescue operations of a half day to several days. Because the chances of saving partially buried injured people decrease exponentially with time, these unnecessary delays are intolerable.

The formation of an international consortium, to include loss estimators, civil defense officials, local seismologists, and rescuers, can solve this problem. This consortium should foster understanding of the quality and limitations of loss estimations, and put in place procedures that allow the evaluation of all information jointly by disaster managers and seismological experts in real time by telephone. Annually, the positive and negative experiences during the disasters of the year should be evaluated in a workshop debriefing to improve the rescue success.

In order to improve loss estimates min developing countries, the International Association of Seismology and the Earth's Interior has formed a working group that will foster improvements in the techniques to estimate losses and the data sets necessary. The planned activities of this working group are summarized by Wyss (2000a).

(B) Application of satellite images to classify building stock. Details concerning the building stock in developing countries are poorly known, and the numbers of buildings are far too large to make feasible the individual inspection of buildings. Thus, there is a need to use a combination of information from satellite images, the engineering reports encyclopedia, and limited inspection on the ground to increase information on properties of the building stock worldwide.

On the basis of satellite images, three-dimensional models of cities can be developed, with the height of every building calculated from its shadow, or from its side visible in the image. Using the height, an approximate assignment of buildings to one or two groups of a given fragility class is possible. The fragility (inability to withstand shaking) is given as a probability that a building may sustain a certain degree of damage (e.g., collapse) as a function of intensity of ground shaking. The fragility curves themselves should, in our opinion, still be derived by civil engineers by inspecting selected buildings on the ground. If the distribution of buildings into classes is known from satellite images, the inspection on the ground can be reduced to a couple of man-weeks per city. The cost of the necessary image enhancement work is not prohibitive. To further reduce the costs of classifying buildings some short cuts are possible. For example, in relatively homogeneous sections of cities with similar buildings the 3D enhancement may be performed for one, or a few, buildings only. Then the buildings are counted and assume to belong all to the same type.

WAPMERR has collected satellite images for 700 cities in earthquake prone areas in developing countries. The resolution is 60 cm. From these images, the height of buildings can be estimated with errors in the range of 1 to 5 m, with the lower and higher numbers applying to low and high buildings, respectively.

CONCLUSIONS

Losses due to earthquakes in developing countries can be estimated, based on modeling of the probable effects of the strong ground motion, within 1 to 2 hours and anywhere on Earth. The accuracy of these estimates is good enough for rescue teams and civil defense officials to make informed decisions whether or not to mobilize and at what scale. However, the method needs refinement and the data sets on properties of the building stock need to be improved. Three-dimensional modeling of cities, based on satellite images is necessary to cover the great numbers of cities at risk in developing countries. From these city models, the distribution into fragility classes and these classes themselves can be established in conjunction with relatively brief surveys on the ground by engineers.

A strong obstacle for real time estimates to be useful is that many decision makers are not familiar with the nascent capability to reasonably reliably estimate losses in real time after earthquakes. As a consequence, offers of help by international rescue teams are turned down at first when they could help, which leads to unnecessary deaths and suffering. It is proposed to correct this problem by forming an international consortium of loss estimators, rescue specialists and civil defense officials, which will implement advanced routines to deal with earthquake disasters in real time, internationally.

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REFERENCES

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