Discussion

The Hazard From Earthquakes in the Boston Area by P.J. Barosh, Vol. 4, No. 1, Spring 1989, pp. 65-78

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The article, "The Hazard From Earthquakes in the Boston Area," summarizes some of the research that has been performed, as well as the data that have been gathered, in recent years on the seismic hazard in the Northeastern United States. The article makes extensive use of two studies performed for the Massachusetts Civil Defense Agency (MCDA), one of which was not referenced in the article,[1] even though the author participated in the study, and one which was cited as Reference 26 in the article.[2] This discussion is intended to provide some additional background on the MCDA studies in order to clarify their intended use, and to express more uncertainty regarding the current state of knowledge of Northeastern U.S. seismicity than may be implied in the article.

Of primary concern is that this article implies that a great deal is now known about Northeastern U.S. seismicity. This concern is based on the author's statements that:

- The cause of earthquakes in the Northeast U.S. is subsidence of local areas near coastlines, which re-activates old faults.
- The general areas of relatively high (seismic) activity are now well-defined, and the historically active areas continue to be active.

Although subsidence is a possible cause of some earthquakes, it is not a proven one. There are no geologic structures in the Northeast U.S. that have been proven to cause earthquakes. The two largest earthquakes that have occurred in the Northeast U.S. area in the past 50 or so years are the magnitude 5.8 January 1982 Miramichi, New Brunswick, event and the magnitude 5.9 November 1988 Saguenay, Quebec, event. These events occurred in non-coastal areas not normally associated with subsidence. These areas also showed little historical seismic activity, as may be clearly seen on Figure 1 (p. 67) of the author's paper.

Also, Ebel has indicated that although the extensive instrumental monitoring of low magnitude earthquakes that has been done in the past 10 to 15 years has indicated that most historically active areas remain active, the Cape Ann area has been quite inactive during this period.[3] Do these findings mean that an earthquake there is imminent, or that the area can no longer be regarded as an active earthquake source? For purposes of earthquake preparedness in the Boston area, it is prudent to consider Cape Ann to be "active" until proven otherwise. However, the current state of knowledge is such that there are limited means to establish a specific region as "inactive," and virtually no methods to accurately define the maximum earthquake that may occur in a given local area. Certainly there is a great deal more now known about Northeast U.S. earthquakes than there was ten to twenty years ago, but there is a long way to go before the seismicity of the area can be considered to be well-defined.

In the mid-1980s, the MCDA undertook a significant study of the potential for losses (of life and property) due to earthquakes in the Boston area. This study consisted of three phases:

1. Evaluate the historical seismicity and potential sources of future earthquakes, and recommend locations and magnitudes of "study"-basis earthquakes. This work was performed by a committee of eight local geologists and seismologists, chaired by Professor Toksoz of the Massachusetts Institute of Technology.[1] The controlling earthquake for the Boston area was chosen to be a magnitude 6.25 event occurring off the coast of Cape Ann. This was judged to be the "Maximum Credible Earthquake" for the area, and was chosen to be 0.5 magnitude unit and one Modified Mercalli intensity unit higher than the 1755 earthquake.

2. Perform a geologic mapping study of eastern Massachusetts in order to identify areas with the potential to amplify earthquake ground motions. Portions of this study were reproduced in Table 6 (p. 76) and Figures 8 (p. 76) and 9 (p. 77) of the author's article, which were obtained from the second MCDA study.[2]

3. Based on the previous two studies, in combination with data such as population density and structure use and types, estimate the losses that would result if the "study" earthquake were to occur. This portion of the study was performed by URS/John Blume Associates, in coordination with the MCDA and the Massachusetts Institute of Technology, and assisted by Simpson Gumpertz & Heger, Inc., and Haley & Aldrich, Inc.

As stated above, the purpose of the MCDA study was to estimate potential earthquake losses, not to allow site-specific analysis of earthquake ground motions. The mapping that was performed for the second item noted above is not sufficiently accurate for a site-specific study. Also, liquefaction potential was not explicitly considered in the mapping.

It would be interesting to learn why the author now considers the 6.25 magnitude of the MCDA "study" earthquake to be too low, since he participated on the subcommittee that produced the magnitude 6.25 recommendation for the hypothetical Cape Ann event.

The subject of the Modified Mercalli scale intensity increases assigned to soil profiles in the second MCDA study and reproduced in the author's Table 6 (p. 76),[2] which was criticized in the article as being too high, was much discussed by the participants in the MCDA study. The following reasoning formed the basis for the Haley & Aldrich assignment of the intensity increases:

1. The intensity attenuation relationship specified by the MCDA for use in the study was the following:[4]

$$I = -1.43 + 1.79\, m_b - 1.83 \log R - 0.0018\, R \quad (1)$$

where:

I = the intensity at a distance R (in kilometers) from the epicenter of a body-wave magnitude m_b earthquake.

The intensity calculated from this relationship is for "average" foundation conditions, and was based on multiple regression studies of data from four earthquakes: 1940 Ossipee, New Hampshire; 1944 Massena, New York; 1973 Quebec-Maine border; and 1976 Rhode Island. Although soft soils are certainly present in these areas, it was reasoned that the "average" foundation condition for a statistical analysis of the intensity (damage) data was certainly glacial till or relatively thin, dense glacially-deposited soils. Since the ATC 3-06 document used as the basis for the intensity increases considers both bedrock and dense soil deposits less than 200 feet thick as causing no significant amplification,[5] it was concluded that unit intensity increases for poorer foundation soils should be applied to the "average" foundation condition.

2. There is no debate that the 1755 Cape Ann earthquake produced intensity VII damage from Cape Ann to Scituate, including the "poor" soil areas of Boston, as shown on the author's Figure 4 (p. 70) and discussed in the first MCDA study.[1] Since the MCDA "study" earthquake is defined as being one intensity unit higher than the 1755 Cape Ann event, intensity VIII damage would be expected in the areas that experienced intensity VII in 1755. At the 75-kilometer distance from the Cape Ann epicenter to Boston, Equation 1 predicts intensity V for the 1755 Cape Ann earthquake, and intensity VI for the MCDA "study" earthquake. Therefore, a +2 increase in intensity is necessary to explain the observed 1755 damage, and likewise would result in predicted intensity VIII damage in the Boston area for the MCDA "study" earthquake.

3. In the first MCDA study, the committee clearly states on pages 16 and 17 that a +2 intensity increase should be applied to the "average" foundation condition attenuation relationship for areas of "filled land."[1]

Therefore, there was and is a rational basis for the intensity increases assigned in the MCDA study for poor soil conditions.

However, the fact is that not all structures within an area that is assigned a given intensity (for example, intensity VIII) shaking will suffer such damage. A reasonable assumption might be that intensity VIII damage would be the highest expected in the area, since the assigned intensity in an area may reflect the worst soil conditions and the worst construction, and it would not be appropriate to assign this damage level to all buildings in a loss study area. Buildings of good design and construction would suffer less damage than those poorly constructed. Therefore, in a loss study such as that performed by the MCDA, it is desirable to assign a percentage of structures that may be damaged in a given area of equal intensity, based on studies of damage from previous earthquakes. This methodology was followed in the MCDA loss study.

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3. Ebel, J., "The Seismicity of the Northeastern United States," *Proceedings on the Symposium on Seismic Hazards. Ground Motions. Soil-Liquefaction and Engineering Practice in Eastern North America.* National Center for Earthquake Engineering, October 20-22, 1987, Tuxedo, New York, Technical Report No. NCEER-87-0025, December 1987, pp.178-188.

4. Klimkiewicz, G., personal commun., 6 July 1983.

5. Applied Technology Council, "Tentative Provisions for the Development of Seismic Regulations for Buildings," *ATC Report 3-06*, 1978.