A NEAR REAL-TIME SEISMIC CONSEQUENCE ASSESSMENT METHOD BASED ON REAL-TIME SEISMOLOGY

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ABSTRACT :
A near real-time seismic consequence assessment method as emergency response decision support system is presented. It can be used immediately after an earthquake to assess the probability of various damage states of buildings, economic losses and casualty. As the technology of seismic instrumentation, telemetry, communication, computers, and data storage facility has advanced, the real-time seismology for rapid post-earthquake notification is essentially established. The magnitude of earthquakes and location of epicenters have come to be estimated urgently in a few seconds based on observed data of P wave. Research for real-time earthquake engineering is still underway. In this paper, we have developed an immediate evaluation method for earthquake damage of buildings by combining the early earthquake warning and seismic consequence estimation. The seismic consequences are represented by a function of earthquake magnitude, epicenter distance and site condition. These seismic consequence surfaces can be constructed by dynamic analysis of buildings under various conditions at ordinary time. As a result, the various damage states of RC buildings and economic losses can be evaluated very quickly for seismic rapid reporting system by the method proposed based on real-time seismology. The near real-time seismic consequence assessment can be issued, in addition to the epicenter and magnitude. It would benefit earthquake emergency response operations greatly and help to establish real-time earthquake engineering as future means of reducing disaster damage.

KEYWORDS: Real-time seismology, real-time earthquake engineering, seismic consequence assessment, early earthquake warning

1. INTRODUCTION

Today, real-time systems are capable of providing basic earthquake information within a few seconds. Recent advances in seismic sensor technology, data acquisition systems, digital communications, and computer hardware and software make it possible to build reliable real-time earthquake information systems (Kanamori et al., 1997). Seismologists developed real-time seismology which provides us efficient methods for rapid estimation of earthquake event features such as magnitude and location by limited information of the P- waves (Allen and Kanamori, 2003). The earthquake information can be effectively used for postearthquake emergency response, and under favorable circumstances, early warning. Also, gaining scientific information quickly has its own merit for better understanding the process through strategically deployed instrumentation, planned field works and public information services (Kanamori et al., 2005).

For timely seismic emergency response, rapid and accurate determination of the extent and distribution of the damage during and immediately following a major earthquake is an important issue, especially in the operation of seismic early warning system. Many researchers investigated the relationships between seismic damage and the parameters of ground motion such as seismic intensity (MMI), peak ground-motion acceleration (PGA), peak ground motion velocity (PGV) (ATC, 1985, Kirch, etal., 1997). The distribution of ground motions may be mapped within minutes of post-initiation of a strong earthquake by the rapid reporting system, however, we need to identify the areas that are most likely to sustain damage as early as possible. Therefore, for seismic early-warning and immediate emergency response purposes, it is often more important to know the spatial distribution of building damage for the seismic event given magnitude and location.

The objective of this paper is to present an approach to estimate building damage distribution in terms of real time parameters of the earthquake and the earthquake consequence is represented by magnitude, distance. Combining real-time seismology with the method for modeling damage to buildings and estimating casualties in terms of magnitude and epicenter distance, the near real-time damage assessment methodology is developed to help emergency responders to make appropriate decisions and take quick actions.

2. THE PROCEDURE OF SEISMIC DAMAGE ESTIMATION IN TERMS OF MAGNITUDE, DISTANCE AND SITE CONDITION

The potential for damage depends on many parameters, such as the earthquake magnitude, location, proximity to population in the area, intensity and frequency content of ground motions, and others. To consider these factors, a source-path-site-structure is considered simultaneously when the seismic consequence assessment is performed (Wen and Chau, 2007). Assuming the magnitude, seismic source mechanism, epicentral distance, and soil condition, the ground motion is determined by attenuation relationship such as Eq. (1).

$$\ln S_a(T) = b_1 + b_2(M-6) + b_3(M-6)^2 + b_5 \ln r + b_v \ln \frac{V_S}{V_A} \tag{2.1}$$

Structural responses of reinforced concrete building subjected to different seismic ground motions are determined by an equivalent lateral force method. Taking account of structural nonlinearities as well as random of ground motion, the stochastic response and probability distribution of building damage are calculated. The probability density function of story ductility μ which may be expressed in lognormal distribution can be estimated.

To allow for magnitude, distance and site condition, and to characterize the effects of the shape and intensity of response spectrum curves on probability distribution of damage among the different damage states, an alternative approach is furthermore adapted to represent the probability distribution of damage. Damage probability distribution for various damage states of a specific building is represented as the joint probability surface of magnitude and distance intersection points at given site condition. Using the threshold values of the ductility factor as integration limits, the probability of various damage states for a given ground motion can be integrated as:

$$P\left[D_j \middle| M, R\right] = \int_{\mu_j}^{\mu_{j+1}} \frac{1}{\xi\mu\sqrt{2\pi}} \exp\left[\frac{-(\ln\mu - \lambda)^2}{2\xi^2}\right] d\mu \tag{2.2}$$

where μ_j, μ_{j+1} is respectively the threshold of ductility factor for damage state D_j and D_{j+1}. The fragility surfaces characterized by magnitude, distance and site condition can be derived for different damage state.

3. NEAR-TIME SEISMIC DAMAGE ASSESSMENT

The outline of near real time assessment method for earthquake damage of buildings is shown in Figure 1. The method is composed of two steps. The first step is the preparatory evaluation at ordinary time. The preparatory evaluation includes establishment of fragility surfaces and consequence surfaces under various conditions (in different magnitude, distance and site condition) just mentioned in preceding section. The near real timeevaluation consists of the estimation of distance from epicenter at building site based on the early earthquake warning, the near real time evaluation of earthquake damage based on the fragility surfaces and other consequence surfaces in terms of magnitude and distance and the information transmission to the site. Based on modeling seismic consequences (in terms of magnitude and distance) and databases of building inventories, the near real time earthquake impact estimate may be given very quickly.

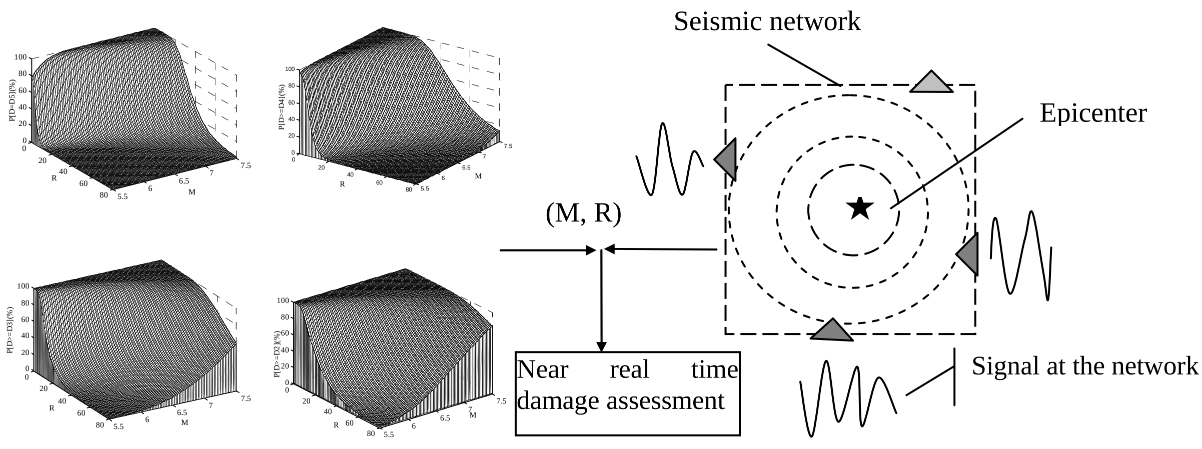

Figure 1 Flow of near real-time damage assessment method of earthquake damage

4. DISCUSSION AND CONCLUSIOND

Seismologists have developed several procedures to estimate the event's magnitude based on limited information of the P-waves in the first few seconds of the earthquake. Similarly the location, and the source-to-site distance, may be retrieved by the sequence of network stations triggered. This allows the evaluation of the structural performance, furthermore consequence loss before the quake strikes.

A near real time seismic damage evaluation method for earthquake damage by combining real-time seismology and earthquake consequence analysis was developed. As a result, the earthquake damage of buildings can be evaluated by the method proposed quickly. As the real-time seismology advances and tools for modeling damage to buildings and lifeline, and casualties are developed, incorporating real-time seismology with seismic consequence estimation methodology for given the source parameters such as magnitude will help to accomplish the goal of building real time earthquake information systems, which may provide a means (a tool used to portray magnitude, location, the extent of ground motions and the extend and distribution of damage) damage for modern urban regions to cope effectively with the aftermath of the major earthquakes.

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REFERENCES

Kanamori, H., E. Hauksson, and T. Heaton. (1997). Real-time seismology and earthake hazard mitigation, *Nature* 390, 461-464.
Allen RM, Kanamori H. (2003). The potential for earthquake early warning in southern California. *Science*, 3000, 786-789
Kanamori H.(2005). Real-time seismology and damage mitigation. *Annual Review of Earthquake and Planetary Sciences* 33: 5, 1-20.
ATC-13 (1985). Earthquake Damage Evaluation Data for. California, Report ATC-13, Applied Technology Council,. Redwood City, California.
Kirch, C.A., Nassar, A.A Kusku, D. Holmes, W.T. (1997). Development of building damage functions for earthquake loss estimation, *Earthquake Spectra*, 13, 663-682.
Karim K R, Yamazaki, F. (20003). A simplified method of constructing fragility curves for highway bridges. *Earthquake Engineering and Structural Dynamics* 32:10, 1603-1626.

Wu, Y.M., Kanamori H. (2005). Rapid assessment of damage potential of earthquakes in Taiwan from the beginning of *P* waves. *Bull. Seism. Soc. Am*. 95, 1181-1185

Wen ZP, Chau KT,(2008). Seismic fragility analysis based on magnitude, distance and site condition. Earthquake Engineering and Structural Dynamics (submitted)