8th International Conference on Seismology & Earthquake Engineering
11-13 Nov. 2019, Tehran, Iran

SAFETY EVALUATION OF BUILDINGS BY AFTERSHOCKS

Mohammad Ali ASGHARI VARZANEH
Ph.D. Student, IIEES, Tehran, Iran
mohammad.ali.asghari@stu.iiees.ac.ir
Majid MOHAMMADI
Associate Professor, IIEES, Tehran, Iran
mohammadi@iiees.ac.ir

Keywords: System identification, Post-earthquake building assessment, Decision-support system, Structural safety, Forced-vibration measurements

Earthquakes can affect the performance of civil structures significantly. Iran is located on Alpine-Caucasian-Himalayan belt, so earthquakes are major threats for the structural stability and safety in this country. Immediately after a seismic event, safety evaluation of buildings in the earthquake stricken area is essential for decision-making. In other words, post-earthquake structural safety assessment is a key to determine whether an earthquake-damaged structure is safe to re-occupy or not. Current assessment practices rely mostly on visual inspections conducted by experts and assign green, yellow or red tags on buildings that are apparently safe, restricted for use and unsafe to occupy, respectively. ATC-20 is one of the most common guideline for this practice; it has a three-level evaluation methodology: rapid evaluation (emphasis is on the exterior of the building), detailed evaluation (requires a thorough examination of the interior and exterior of the building), and engineering evaluation (when visual inspections are not sufficient to determine damage to the building).

Some researchers showed that the assessment results of visual inspections are subjective (Marshall et al., 2013; Galloway et al., 2014). Additionally, in an earthquake stricken area with widespread damage probably there are not enough well-trained engineers for safety assessment of the buildings. Being time consuming is another drawback of this method specially when there is a potential need for multiple inspections of some buildings, it conflicts with the need for rapid decision-making. Hence, there will be a need for a methodology which can complement visual inspections. For this purpose, some decision-support systems are devolved by different researchers. Mitrani-Reiser et al. (2016) introduced the "Virtual Inspector", which is used to probabilistically estimate building safety and assign corresponding tags. Goulet et al. (2015) proposed a Bayesian probability updating scheme for vulnerability curves in order to reduce the number of buildings to inspect without losing information related to the damage on a city-scale. Jalayer et al. (2009) proposed a methodology could be used for post-earthquake decision-making between a set of viable actions such as, evacuation, shut-down, repair and re-occupancy.

Since an important structural-identification application is residual-capacity assessment of earthquake-damaged structures, it can be an attractive method to overcome shortcomings of visual inspection. Reuland et al. (2019) proposed a model-based data interpretation method for determining structural safety based on system identification through ambient-vibration measurements. There are several system identification methods based on structural response. A guideline for using the response-based methods is given in Table 1 based on the pros and cons of those methods (Xuan Kong et al., 2017).

As ambient vibration measurements have a very low amplitude of excitation, using forced vibration measurements under aftershocks can be a natural response to this drawback; after a rare earthquake there is the imminent risk of aftershocks with rich frequency content which creates the opportunity for an objective post-earthquake assessment. This paper is focused on the safety evaluation of a building with a moment resistance frame, previously damaged by a mainshock, through aftershocks. The outcomes of this study can be useful for creating a new support decision system for post-earthquake safety evaluation of earthquake-damaged structures.

Table 1. Guideline of Response-based Methods (Xuan Kong et al., 2017).

Data Domain	Representative Methods	Advantages and Disadvantages
Time domain	Ibrahim method Random decrement ERA ARMA family Wavelet analysis EMD and HHT RSSI, SSI-DATA, SSI-COV KDE	Advantages: straightforward to use the time domain responses Advantages: eliminate the need to perform frequency transformation, no associated errors such as leakage and truncation, preserved nonlinear behavior Disadvantages: significant effects of noise difficult to interpret signal information
Frequency domain	FRF shapes FRF curvature Transmissibility Peak picking FDD	Advantages: abundant information on structure dynamic behavior, contains frequency information in a wide range without further extraction and processing Disadvantages: some requires the input information the features are too abstract
Modal domain	Natural frequency Mode shapes and curvatures Modal strain energy Strain mode shapes Dynamically flexibility High-order derivatives Signal processing based	Advantages: modal properties are physically meaningful easy to be interpreted or interrogated, from output-only data and not require artificial forces Disadvantages: lose much of the information numerical errors caused by inaccurate curve fitting

REFERENCES

ATC (1995). *ATC-20 Procedures for Post-earthquake building safety evaluation procedures*. Redwood, CA: Applied Technology Council.

Galloway, B., Hare, J., Brunsdon, D., Wood, P., Lizundia, B., and Stannard, M. (2014). Lessons from the Post-Earthquake Evaluation of Damaged Buildings in Christchurch. *Earthquake Spectra*, *30*(1), 451-474. doi: 10.1193/022813eqs057m.

Goulet, J.A., Michel, C., and Kiureghian, A.D. (2015). Data-driven post-earthquake rapid structural safety assessment. *Earthquake Engineering & Structural Dynamics*, *44*(4), 549–562, doi: 10.1002/eqe.2541.

Jalayer, F., Asprone, D., Prota, A., and Manfredi, G. (2010). A decision support system for post-earthquake reliability assessment of structures subjected to aftershocks: an application to L'Aquila earthquake, 2009. *Bulletin of Earthquake Engineering*, *9*(4), 997–1014. doi: 10.1007/s10518-010-9230-6.

Kong, X., Cai, C., and Hu, J. (2017). The State-of-the-Art on Framework of Vibration-Based Structural Damage Identification for Decision Making. *Applied Sciences*, *7*(5), 497, doi: 10.3390/app7050497.

Marshall, J.D., Jaiswal, K., Gould, N., Turner, F., Lizundia, B., and Barnes, J.C. (2013). Post-Earthquake Building Safety Inspection: Lessons from the Canterbury, New Zealand, Earthquakes. *Earthquake Spectra*, *29*(3), 1091–1107. doi: 10.1193/1.4000151.

Mitrani-Resier, J., Wu, S., and Beck, J.L. (2016). Virtual Inspector and its application to immediate pre-event and post-event earthquake loss and safety assessment of buildings. *Natural Hazards*, *81*(3), 1861–1878. doi: 10.1007/s11069-016-2159-6.

Reuland, Y., Lestuzzi, P., and Smith, I.F. (2019). A model-based data-interpretation framework for post-earthquake building assessment with scarce measurement data. *Soil Dynamics and Earthquake Engineering*, *116*, 253-263. doi: 10.1016/j.soildyn.2018.10.008.