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A QUANTITATIVE STUDY ON THE RESILIENCE OF HOSPITALS AND MEDICAL CENTERS (CASE STUDY OF MADANI HOSPITAL IN KARAJ)

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One of the main challenges of this century for high-seismic cities is to prepare for natural disasters, especially earthquakes to reduce the vulnerability and increase seismic resilience. Seismic resilience indicates the ability to maintain a level of functionality or performance of a building, bridge, lifeline network, or community over a specified period of time determined as a T_{LC} or control time (Figure 1). Resilience is defined geometrically as a normalized shaded area below the functional diagram of the system, determined as $Q(t)$. $Q(t)$ is an invariant stochastic process that is measured as a percentage in terms of the dimensionless function of time.

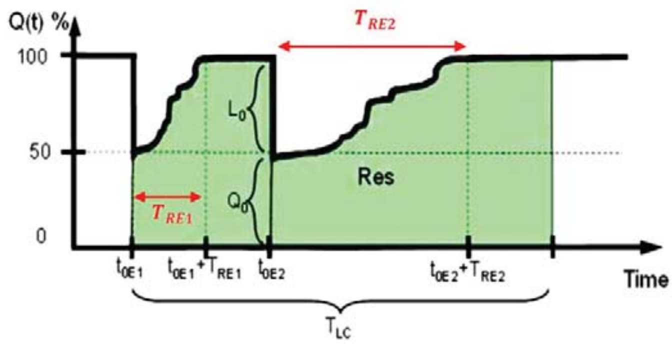

Figure 1. Schematic view of resiliency for two events.

In the case of multiple events, each event is expressed as a continuous piece of independent function (Figure 2). Mathematically, the resilience of several events can express with Equation (1).

$$\bar{R} = \frac{1}{N_I}\sum_{I=1}^{N_I}\left\{\frac{1}{N_E}.\sum_{E=1}^{NE}\frac{1}{T_{RE}}.\int_{t_{oE}}^{t_{oE}+T_{RE}}\left\{\begin{array}{c}\left[1-L\left(I,T_{RE}\right)\right]\left[\begin{array}{c}H\left(t-t_{0E}\right)+\\ -H\left(t-\left(t_{0E}+T_{RE}\right)\right)\end{array}\right].\\ .\alpha_R.f_{Rec}\left(t,t_{0E},T_{RE}\right)\end{array}\right\}.dt.P_E\left(0,T_{LC}\right)\right\}.P\left(I\right) \quad (1)$$

where is the number of expected event E in the lifetime (or control period) of the system T_{LC}, N_I is the number of different intensities for events that are expected during the control period T_{LC}; T_{RE} is the recovery time for the event E; t_{0E} is the time of occurrence of event E; L (I, T_{RE}) is the normalized damage function; f_{REC} (T, t_{0E}, T_{RE}) is the recovery function; $P(I)$; is the probability of occurrence of the event with intensity at the time interval T_{LC};

P_E (0, T_{LC}) is the probability that the occurrence of an event E repeats at the time interval T_{LC}; α_R is the recovery coefficient and $H(T_0)$ is the Heaviside step function.

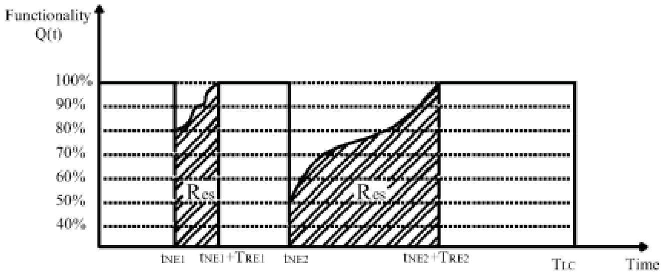

Figure 2. Resilience of several independent events (Cimellaro et al., 2006).

In order to reduce the vulnerability and increase seismic resilience, it is necessary to investigate the resilience of the urban structures and its physical elements, such as buildings especially those related to medical centers. Meanwhile, increasing seismic resilience for medical buildings such as hospitals and healthcare centers in large and seismic cities due to high costs, time, executive problems, and budget constraints become a major issue for authorities and urban decision-makers. So far, few researches have been done on the resilience of healthcare centers and hospitals, mostly in the form of qualitative studies. In qualitative studies, it is not possible to provide a precise indicator for estimating the amount of resilience increases in proportion to the cost. For this reason, it is necessary to calculate current status of hospitals resilience by providing indicators and quantitative methods, and if required, to increase their resilience, using the methods of retrofit and rehabilitation, calculate the optimal option based on the cost-benefit function.

In this paper, an analytical framework was developed to estimate the resilience of hospitals and healthcare centers. The method was applied to quantitatively calculate seismic resilience for the existing status of Madani hospital in Karaj city. Furthermore, a possible increase in seismic resilience of the hospital for different states of retrofitting (such as partial or full retrofit options) in comparison to the existing situation was investigated for an earthquake with 2500 years return period revealed. The results of assessment for Madani hospital showed 10 and 20 percent increase in resiliency for partial and full retrofit options, respectively. The comparison between the estimated costs for different retrofitting options and the amount of increase in resiliency make the decision makers possible to choose the optimal option with the least cost and the most resilience with regard to budget limitations.

REFERENCES

Bruneau, M., Chang, S.E., Eguchi, R.T., and Reinhorn, A.M. (2003). A framework to quantitatively assess and enhance the seismic resilience of communities. *Earthquake Spectra*, *19*(4), 733-752.

Chang, S.E. and Shinozuka, M. (2004). Measuring improvements in the disaster resilience of communities. *Earthquake Spectra*, *20*(3), 739-755.

Cimellaro, G.P., Reinhorn, A.M., Bruneau, M. (2006b). Quantification of seismic resilience. *Proceedings of 8th National Conference of Earthquake Engineering*, Paper 1094, San Francisco, California.

FEMA (2005). HAZUS-MH Version 1.1, FEMA`s Software Program for Estimating Potential Losses from Disasters, Technical Manual. *Federal Emergency Management Agency and U.S. Army Corps of Engineers*, Washington D.C., Available at: www.fema.gov/hazus.

Scott, B., Miles, S., and Chang, E. (2006). Modeling community recovery from earthquakes. *Earthquake Spectra*, *22*(2), 439-458.