Earthquake Resiliency – Where Do We Stand?

By John A. Dal Pino, S.E.

John A. Dal Pino is a Principal with FTF Engineering located in San Francisco, California. He serves as a member of the STRUCTURE Editorial Board and may be reached at ***jdalpino@ftfengineering.com****.*

Resiliency is "the capacity to recover quickly from difficulties; toughness." To a structural engineer, this means a strong yet ductile structure that is survivable and repairable in the face of severe environmental loads, such as major earthquakes. In terms of earthquake resiliency, where does our building inventory stand? We have come a long way as you will see, but we have a long way to go.

A generation ago, farsighted policymakers in California, urged on by leading structural engineers, implemented measures to strengthen unreinforced brick masonry buildings, eliminate brick parapet falling hazards, and retrofit concrete tilt-up buildings. Many private companies and public agencies embarked on ambitious programs to strengthen and improve existing structures. Today, cities throughout California, including San Francisco, Los Angeles, and Oakland, have implemented programs to retrofit soft-story wood framed residential buildings of which there are several thousand in San Francisco alone. On the existing building front, excellent progress is being made.

However, what about new buildings? The building code is more comprehensive than ever and has incorporated many of the lessons that were learned from past earthquakes, so we are clearly better off. But the building code is a prescriptive document (you shall do this, and you shall not do that) and remains somewhat of a black box. Some argue that the more comprehensive the code becomes, the more of a black box it becomes. Exactly what does a code compliant building provide society regarding earthquake resiliency?

The *California Building Code* states that its purpose is to "establish the minimum requirements to safeguard the public health, safety, and general welfare…" This type of language has been in the code for a long time and is in most other state building codes. However, in terms of safety (or life-safety, being the term used by structural engineers), what does it mean exactly and what structural performance and reliability does it imply?

Building codes of the past were generally silent on the issue and did not provide the public with an explanation of the performance that a building owner might expect from a compliant building. Unfortunately, most engineers probably gave the topic little thought either. Code compliance is generally equated with safety and solidity, and that settled that. We all know that in terms of earthquakes, the *maximum considered earthquake* or MCE is not the largest earthquake that can happen at any given site. The word "considered" in the name should be warning alone that there may be larger earthquakes that have *not been considered*. The "C" used to stand for *credible*, which implied something that is near the top, but even that was misleading in that there is significant variability in the data.

With the current focus on climate change, global warming, and recycling/conservation, as evidenced by the establishment of LEED design, the United States Resiliency Council (USRC) and the REDi Rating System, the public, architects, and engineers have started to focus on smarter design processes. Using certain kinds of lumber, or recycled steel, or waste coal products in construction certainly help the environment, but when the big earthquake hits and the resulting damage requires the building to be torn down because it lacks resiliency, how "green" was it really? Perhaps the greatest contribution that structural engineers can make to green design is to engineer a *resilient* structure – a structure that can handle a range of extreme environmental loadings and stay in service.

Getting back to the building code, how earthquake resilient are buildings being designed to the code today? Until the past few code cycles, most engineers probably did not know. Fortunately, the commentary to Chapter 1 in ASCE 7-10, *Minimum Design Loads for Buildings and Other Structures* provides insight. Because the code permits design using Performance-Based Procedures (i.e. alternative means of compliance) in Section 1.3.1.3, the code writers had to give engineers a performance standard by which their designs could be evaluated. With regard to earthquakes, Table C.1.3.1b, titled *Anticipated Reliability (Maximum Probability of Failure) for Earthquake*, provides the information and a window into how resilient our structures are. For Risk Category II buildings (most buildings), the commentary states that society can expect *total or partial collapse* to occur in *10% of new buildings* in the maximum considered earthquake and *failures that could result in endangerment of individual lives* to occur in *25% of new buildings* in the MCE. The actual damages will most likely be far greater because existing buildings designed to lower standards should fare worse. Moreover, there is always the possibility of earthquakes that *are not considered* (i.e. greater than the MCE).

How resilient then are our buildings in high seismic regions? You can be the judge of that. A 10% rate of total or partial collapse may not be a concern if you believe an MCE earthquake will not happen. But in reality, they do. The Christchurch area of New Zealand experienced one in 2011 and suffered tremendous devastation. Perhaps the 25% endangerment of individual lives will sharpen our focus?

Hopefully, this insight into the expected resiliency of our code-compliant new buildings, and that of our older existing buildings, will motivate structural engineers to educate their clients about the expected performance of perhaps their greatest financial assets, and the ones that protect their friends and families. For a small premium, should we design new buildings to standards in excess of the code minimum to achieve resilience?▪