Acceptable Collapse?

Thoughts on Building Seismic Performance Objectives

By Reid Zimmerman, P.E.

"Danger. Extremely Flammable. Fire/Explosion Hazard." These words are printed in cautionary lettering on a little green propane tank used for my camping stove. Equally interesting, though not quite as dramatic, is the word "overbuilt" printed just above the manufacturer's name. In context with the outcome of failure – an explosion – overbuilt seems stout, safe and ultimately reassuring. Contrast this to the newly stated seismic performance objectives in ASCE/SEI 7-10, *Minimum Design Loads for Buildings and Other Structures*. In words printed for a different audience, ASCE/SEI 7-10 specifies an explicit acceptance of up to a 10% probability of partial or total collapse under Maximum Considered Earthquake (MCE_R) shaking.

You might be thinking to yourself, "I don't remember that being in ASCE 7"; and if you were to consult your trusty ASCE/SEI 7-05, you would be right. But with the publication of ASCE/SEI 7-10, acceptable probabilities of collapse have been explicitly included in the commentary to Chapter 1. They are defined as a 10%, 6% and 3% acceptable probability of collapse given MCE_R shaking for Risk Category II, III and IV structures, respectively. The history of establishing such values dates back many years and has evolved through several FEMA publications. A complete description is beyond the scope of this article and, frankly, should be told by someone older and wiser than myself, preferably while sitting around a campfire. What I can assure you is that (1) it was not settled on without thought, (2) it is in moderate agreement with the implicit assurances of past versions of ASCE/SEI 7, and (3) it will garner additional study in the years to come.

With the rise in popularity of statistics, everything from the outcome of the U.S. presidential election to the chance of rain in Portland, Oregon is being approached within a probabilistic framework. The acceptability of collapse for new buildings should be no different. How are we to say what is "conservative" or "safe" – or for that matter "overbuilt" – without a point of reference? ASCE/SEI 7-10 now provides this probabilistically-based benchmark from which we can look back and, hopefully, move forward.

Let's start with the good. We have no dramatic evidence that buildings constructed to ASCE/SEI 7-05 are especially collapse-prone in earthquakes. It should be acknowledged, though, that we do not have much data in recent years for real earthquakes producing severe shaking in the United States. Given our current knowledge, we can deem a building designed to ASCE/SEI 7-05 as generally acceptable in terms of collapse safety. It follows that, since the probability of collapse for those structures approximately matches the values found in ASCE/SEI 7-10 (confirmed by analytical studies), we are in the right ballpark for acceptable collapse probabilities.

So we know where we are, but do we know where we want to be? A 10% probability of collapse may be both consistent with the intent of the implicit provisions in ASCE/SEI 7 and attainable within the cost expectations of current building owners and developers, but is it "safe enough"? Or, even more perplexingly, could it be "too safe"? In justifying an acceptable probability of collapse, one might naively argue that the only *acceptable* probability of collapse is zero, but this is unattainable (even theoretically) and oversimplifies the issue. Instead, an acceptable probability of collapse would likely grow out of consideration for livability, cost-effectiveness and other concerns of modern society in balance with, but not necessarily in equal proportion to, public safety.

To attain this balance requires the input of the general public. However, with a mistaken belief in "earthquake-proof" buildings still pervasive in society, and misunderstanding of statistics common – I admit to being guilty of this myself at times – is the general public knowledgeable enough to enter into this discussion? Some recent initiatives, such as the building rating system proposed by the U.S. Resiliency Council (**www.usrc.org**), reflect the belief that a system driven by the public can succeed. While it would seemingly be undemocratic to disagree, the concern is over how to educate people so that they may make an informed decision.

Taking a step back, let's ask ourselves why codes change at all. One's first guess might be that they change to make buildings safer. While I agree in principle, I believe that this is only half the story. They really change when the benefit-to-cost ratio of the revised language is favorable, or when new data implies a greater risk than previously anticipated. In the past, the benefit-to-cost ratio had to be presumed or was obvious from earthquake reconnaissance (e.g., out-of-plane anchorage of walls to diaphragms). What was missing, and what the explicit definition of acceptable probability of collapse provides, is a quantitative way of justifying future changes. I understand that not all things can be directly and quantitatively related back to collapse due to our own limitations and the uncertainty inherent in the natural world. Yet shouldn't our goal (and our expectation) be to reduce the acceptable probability of collapse in future versions of ASCE/SEI 7? Isn't that our duty as a profession?

As engineers, we pride ourselves on our ability to envision solutions in the presence of amazing uncertainty and randomness. Rather astoundingly, we do an impressive job of this. However, sometimes this culture comes at the cost of permitting ourselves the freedom to ask difficult questions without immediately worrying about an answer. Is a 10% probability of collapse an acceptable target, or is it simply a product of our engineering culture – an answer to a difficult question using the only information we have? I don't know. I wish it were as simple as being able to state that our buildings are "overbuilt," like my little green camping stove propane tank. I think I'll go camping.▪

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