Not Safe Enough

The Public's Expectations of Seismic Performance

By Keith Porter, PhD, PE and Michael Davis, PhD

Do structural engineers have an ethical obligation to seek public input on how new buildings should perform in earthquakes? What might the public prefer in terms of the right measure of seismic performance, the expected level of performance and reasonable trade-offs between cost and performance?

Historically, developers of building codes established the seismic-performance objectives for new buildings by back-calibrating to prior codes, achieving consistency without dramatic increases in construction costs.

Before 1980, seismic-design requirements in the *Uniform Building Code* (UBC) attempted to ensure a fair degree of life safety through factors that seemed reasonable.[1] In specifying load and resistance factor design (LRFD) for the precursor to the American Society of Civil Engineers (ASCE)/Structural Engineering Institute (SEI) standard ASCE/SEI 7, *Minimum Design Loads for Buildings and Other Structures*, a group of engineers and academics[2] specified quantitative design procedures to ensure an approximate four-percent maximum probability of life-threatening damage based on design-level shaking. (This type of shaking is fairly rare, though prior to seismic micro-zonation, its likelihood varied from place to place within large, state-sized or multi-state zones.)

To ensure the consistent safety of new structural systems, authors of the Federal Emergency Management Agency (FEMA) publication FEMA P-695, *Quantification of Building Seismic Performance Factors* proposed basing design ductility on an objective of no more than 10-percent collapse probability based on maximum-considered-event (MCE, approximately 2,500-year) shaking.[3] Their goal was back-calibrated to match collapse probabilities in code-compliant steel-, concrete- and wood-frame construction. Using the risk-targeted seismic design[4] adopted by ASCE/SEI 7-10,[5] new buildings now are designed to a less than one-percent collapse probability during their 50-year life.

The measure of acceptable seismic performance has changed subtly since the 1980s, because of the transition from allowable stress design to LRFD. However, nobody deliberately chose what constitutes acceptable or unacceptable performance; it always has been assumed that prior design is safe enough. In fact, the structural engineering community never has held a profession-wide debate on acceptable seismic safety. With minor exceptions, nobody has asked the public whether the code's seismic performance measures are the ones that the public cares most about. Moreover, the public was never asked whether the code's objectives are satisfactory or reflect the public's preferences in terms of trade-offs between cost and performance or between one kind of performance and another. Should structural engineers ask what they want? If so, why and how? Consider the ASCE Code of Ethics as a possible source for guidance.

ASCE Code of Ethics

The First Fundamental Canon of ASCE's Code of Ethics requires engineers to hold "paramount the safety, health and welfare of the public."[6] In this sense, the public consists of persons whose lack of information, technical knowledge, ability or conditions for adequate deliberation renders them vulnerable to the power that engineers wield on behalf of clients or employers.[7] The public is a collection or aggregate of people, rather than an organized body—an abstraction, much like a set in mathematics. Its membership varies with the engineering work in question. The public has interests, but, unlike an electorate or corporation, no decision procedure for declaring them, meaning the public has no will of its own.

Engineers always should use the best available information on public safety, health and welfare, insofar as such information is reasonably available. The phrase "best information reasonably available" is subjective. However, at a minimum, it includes (when relevant): information available in standard engineering reference works, whether paper or electronic; information available from employers, clients or colleagues; and information available from other readily accessible sources. The publications of standards-writing bodies for the engineering community, whether professional (e.g., ASCE), governmental (e.g., the U.S. General Services Administration) or independent (e.g., the International Organization for Standardization), may also count.

Similarly, when reasonable, engineers should seek to improve the useful information available concerning public safety, health and welfare. This assumption may appear too demanding, but it's important to emphasize that the search for new information is limited to what is "reasonable." Anything that makes the search unreasonable—constraints of time, budget, law or skill—is enough to suspend the requirement. Additionally, the information need not be sought just because

Public Perception Survey on Seismic Performance Expectations

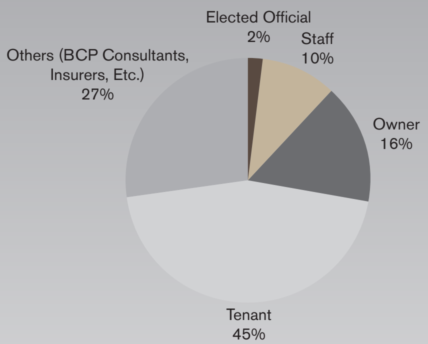

Figure 1: Respondent role.

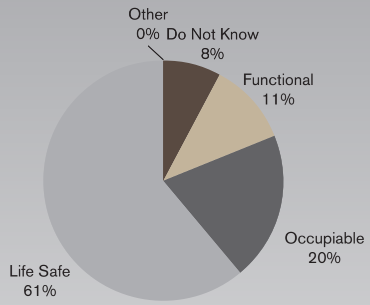

Figure 2: Presumed current seismic performance objective.

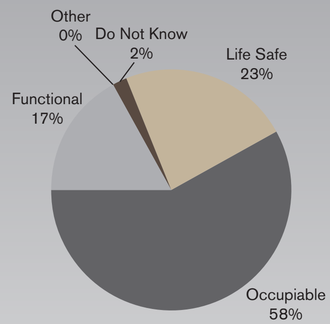

Figure 3: Preferred seismic performance objective.

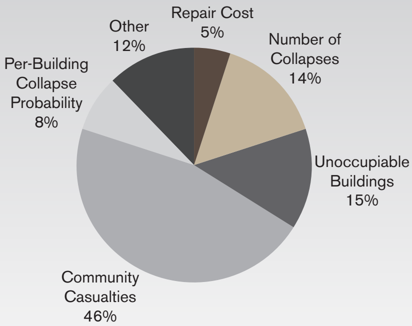

Figure 4: Preferred measure of performance.

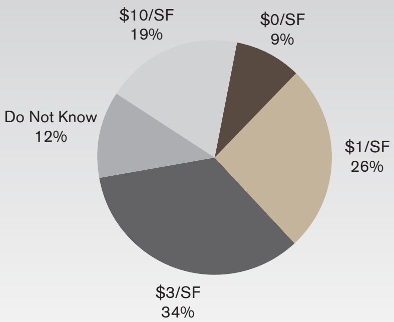

Figure 5: Value of (willing to pay more for) post-earthquake occupiability.

it *can* be discovered or even because it *might* prove intellectually interesting. The information sought must be *useful*—or at least seem likely to be. Engineers who fail to seek to improve useful information about public safety, health and welfare fail to "work for the advancement of the safety, health and well-being of their communities." They also fail to satisfy two fundamental principles of engineering: "[to use their] knowledge and skill for the enhancement of human welfare [when possible]"; and, second, "[to strive] to increase the competence of practitioners and the prestige of the engineering profession [when reasonable]."[6]

From these two propositions, the ASCE Code of Ethics implicitly requires that*, insofar as practical*, the public have a *continuing* part in defining allowable trade-offs among public health, public safety and public welfare in any work of engineering. The public is likely to have a unique perspective and knowledge of what trade-offs should or should not be made—information that engineers typically lack.

Despite the value of public input, the public's participation in much of everyday engineering seems impractical. Members of the public cannot be present at every design meeting, let alone sit beside every engineer as he or she works. Nonetheless, the public can make a substantial contribution even without such pervasive participation. For example, the public can participate in the writing of technical standards on which engineers regularly rely. Obviously, there are objections—even to less-extensive, but still substantial public participation. Despite these, objections do not offer reason enough to give up public participation altogether. Experimenting with public participation is necessary at all stages of standards writing, beginning with a description of the survey that follows.

A Survey of Public Preferences

In 2015, the University of Colorado (CU) and the National Institute of Building Sciences Multihazard Mitigation Council developed a preliminary survey of the public's understanding of and preferences for the seismic performance of new buildings. Because the survey was performed by a public university, it was subject to regulations designed to implement ethical principles and preserve the public trust. The 1966 U.S. Public Health Service (PHS) policy, "Clinical research and investigation involving human beings," requires an institution review board (IRB) to independently review research. The 1974 PHS policy 45 CFR 46 specifies requirements for institutional assurances, IRB review, informed consent and ethical conduct. In 1991, 17 federal agencies issued uniform regulations under the title "Common Rule." The survey discussed here was approved by CU's IRB.

The wording of the preliminary survey was reviewed by a sociologist experienced in the preparation and interpretation of public surveys. Liesel Ritchie, PhD, associate director of the Natural Hazards Center at CU Boulder, felt that "the survey has decent face validity (basically, it is measuring what it looks like it is measuring) and reasonable content validity (referring to the extent to which a measure represents all facets of a given social construct/topic)."

The preliminary survey asked 12 questions. Without repeating the questions verbatim, they included:

1. What is the role of the respondent with respect to the building code (tenant, owner, elected official, etc.)?

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2. What does the respondent think the *International Building Code's* (IBC) seismic performance objective is? (Respondents could choose one of the following answers: life safety, functionality, operability, do not know or other.)
3. What should the *International Building Code's* (IBC) seismic performance objective be? (The survey offered respondents the same answers as point 2.)
4. How should the code measure seismic performance? (Options were collapse probability, total number of collapses, number of unoccupiable buildings, number of human casualties, repair cost, other or a combination.)
5. What are the trade-offs between cost and higher performance? (What does the respondent think the public would be willing to pay for a building that would be largely occupiable after a large earthquake? Options ranged from $0-10 per square foot and the equivalent dollar increase in a monthly mortgage payment.)
6. How important are these issues? (Options ranged from very important to unimportant.)
7. What is the best way to discuss these issues with local government or the community?
8. Questions 8 through 12 asked about a respondent's age, gender, race, education and income.

Survey findings to date follow. *[Editor's Note: "Figures 1 through 5," page 23, represent the findings in graphical form.]* As an initial test, the survey was administered to several meetings of the Association of Bay Area Governments and the Association of Contingency Planners. It represents a convenient sample, a nonprobability method that is often used in preliminary research to get a gross estimate of results without incurring the cost or time required to select a random sample (more on a random sample later). The following results reflect responses from 66 people, of whom 61 percent are building owners and tenants *(see "Figure 1")*. More than half of the respondents (61 percent) correctly understood that the IBC's seismic performance objective is to assure life safety. Most of the remaining respondents (31 percent of the total) believed that new buildings generally are occupiable or functional after a large earthquake *(see "Figure 2")*. Most (75 percent) thought that the code should assure that new buildings be occupiable or functional *(see "Figure 3")*. Few (eight percent) believed per-building collapse probability is the measure of seismic performance of greatest interest. Community casualties (46 percent) and total number of unoccupiable buildings (15 percent) led preferred measures *(see "Figure 4")*. Few respondents (nine percent) believed that the public would be unwilling to pay more for better performance. More than half believed that the public would be willing to pay between $3 per square foot (34 percent) and $10 per square foot (19 percent) more for occupiable buildings *(see "Figure 5")*.

Conclusions

The First Fundamental Canon of ASCE's Code of Ethics requires that the engineer hold paramount the safety, health and welfare of the public. Based on that ethical code, engineers have an implicit responsibility to make a reasonable effort to understand the public's expectations for the seismic performance of code-compliant buildings and its preferences for trade-offs between performance and initial construction cost. As an initial trial of such an effort, the team carried out a preliminary survey of building owners, tenants, elected officials, elected officials' staff and a few others. The preliminary survey was small (n = 66), but the results hint that the public may prefer a different measure of seismic performance than the one employed in the current building code. Additionally, survey respondents preferred better performance (occupiable or functional, as opposed to life safe), and would be willing to pay between one- to four-percent more construction cost (about one-half- to two-percent more purchase price or mortgage payment) for a building stock that would be largely occupiable after a once-in-a-lifetime earthquake (the "big one").

While this preliminary survey lacks a large response and only reflects the understanding and preferences of people in California, it suggests that the public may have very different and more demanding preferences for seismic design provisions in the IBC than the code actually provides. CU, the U.S. Geological Survey and the Institute are following up this preliminary survey with a much broader, random-sample survey of 800 adults in California; St. Louis, Missouri; and Memphis, Tennessee. The random-sample survey will shed light on whether the opinions of these 66 respondents are shared by the population as a whole, and whether geographic location affects an individual's preference for the seismic performance of buildings. JNIBS

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