The Public's Role in Seismic Design Provisions

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Seismic design provisions in the United States reflect structural engineers' experience, technical capabilities, and judgment of what is in the public's interest. Yet the American Society of Civil Engineers' (ASCE) Code of Ethics *implicitly* requires civil engineers to make a reasonable effort to elicit and reflect the preferences of the public, whose lives and livelihoods are at stake, when setting performance objectives. The public seems capable of expressing its preferences clearly, as suggested by the San Francisco Community Action Plan for Seismic Safety and the residential code enhancement adopted by Moore, Oklahoma. And at least one public opinion survey suggests that people in earthquake country prefer better performance than the code intends for new buildings, namely, that buildings should largely remain functional or habitable after a large earthquake. The public also seems willing to pay more for new buildings that meet its expectations. [DOI: 10.1193/081715EQS127M]

INTRODUCTION: NOT SAFE ENOUGH?

Are today's standards for seismic design what they should be? In other work (Porter 2016a), one of us shows that there are severe unintended consequences to the seismic design guidelines (ASCE 2010) that are adopted by the leading national model building code in the United States, namely the International Building Code (ICC 2012). We shall loosely refer to the two documents hereafter refer as "the code," and ignore local modifications to it. The code presents risk-targeted maximum considered earthquake (MCE_R) shaking that is selected so that a code-compliant building, which will have no more than 10% probability of collapse given that level of shaking, will also have no more than 1% collapse probability in 50 years. To be clear: the latter (1%/50 year collapse probability) represents the code's ultimate quantitative seismic performance objective, while the former (10% collapse probability in MCE_R) is the code's indirect means of achieving that objective (Luco et al. 2007). Here, as in FEMA P-695 (ATC 2009), "Collapse includes both partial and global instability of the seismic-force-resisting system, but does not include local failure of components not governed by global seismic performance factors, such as localized out-of-plane failure of wall anchorage and potential life-threatening failure of nonstructural systems" (p. 1–4).

The 1% in 50-year limit on the probability of collapse has an unintended consequence: a much larger probability that a new building will be impaired without collapsing, because more than 60 buildings were red-tagged (rendered unsafe to enter or occupy) or

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yellow-tagged (rendered safe only for limited use) for every building that collapsed in the 1989 Loma Prieta, 1994 Northridge, and 2014 South Napa earthquakes.

The consequence of the per-building limit on collapse probability that we wish to examine here has to do with the fact that a single big earthquake can simultaneously affect all the buildings in a large metropolitan area. Consequently, a building stock that meets the 1% in 50 years goal may experience so much disruption in a single big earthquake—let us refer to it as the Big One, or a once-in-a-lifetime earthquake—that the unimpaired building stock may be insufficient to accommodate all the people who are displaced from the impaired buildings. A Big One in the San Francisco Bay Area (something much larger and closer to the center of a metropolitan area than Loma Prieta or Napa) could displace hundreds of thousands of people and tens of thousands of businesses, forcing them to relocate out of the metropolitan area.

City council members, building owners, and other members of the public appear to be unaware of the seismic performance objective of the International Building Code. When informed of the objective, they are surprised and distressed, as one of us (Porter) has found in many conversations with emergency planners and as a leading southern California seismologist has found in many conversations with political leaders and others in the Los Angeles area (L. Jones, *oral comm.*, 19 Nov 2013). The reason the public is unaware of the code's objectives is that the public has never been involved in developing the objectives. Building officials, engineers, and others develop codes without consulting the general public. In the present work, we examine three questions related to these unintended and apparently unsatisfactory consequences:

1. Are code writers ethically obligated to consult the public's preferences when setting seismic design guidelines?
2. Is the public capable of participating intelligently in decisions about the seismic performance of the building stock?
3. What are the public's expectations for the seismic performance of new, code-compliant buildings?

CIVIL ENGINEERS' ETHICAL OBLIGATIONS TO THE PUBLIC

Civil engineers have long recognized a professional obligation to put the public health, safety, and welfare ahead of other considerations in their work. Structural engineers recognize a similar obligation. ASCE's Code of Ethics (2009) expressly makes this obligation to the public "paramount," while the 2011 Model Code of Ethics of the National Council of Structural Engineers Associations (NCSEA) simply puts the obligation first among the seven tenets, leaving its status to interpretation. This difference does not affect the question dealt with here. Yet the phrase "public health, safety, and welfare" presents at least two problems of interpretation.

First, there is the problem of defining "the public" well enough to determine in what the public health, safety, and welfare consists. Is the public everyone, or only everyone within the engineer's own country, or only everyone outside the organization for which an engineer works, or people identified in some other way? One of us has elsewhere argued that "the public" should be understood as including all those anywhere whose lack of information, technical knowledge, ability, or conditions for adequate deliberation renders them more or less vulnerable to the power that engineers wield on behalf of client or employer. The public is a collection or aggregate rather than an organized body. Unlike an electorate or corporation, it has interests, but no decision procedure—no will of its own. The public is an abstraction (much like a set in mathematics). Its membership varies with the engineering work in question (Davis 1991, 2014). In the present context, however, the public does not include engineers, building officials, or members of the building industry, because these groups largely control the code.

Second, there is the problem of defining the relation between health, safety, and welfare. The phrase in which these three words occur makes the three sound like one single uncomplicated consideration. They are not. Long-term health can compete with short-term safety, welfare with health, and so on. Tradeoffs must sometimes be made between these three considerations or even within a single one. A number of suggestions have been made over the years for how to determine allowable tradeoffs, everything from cost-benefit analysis to shadow markets, from public-opinion surveys to ordinary politics. These suggestions generally share two features. First, they treat the public as entirely passive or, at best, as accessible only through some surrogate (public opinion survey or legislature). Second, they tend to bring in the public, if at all, only near the end of the engineering work, well after most of the important decisions have been made. The public, however brought in, gets to approve or disapprove, not participate in the engineering work as it proceeds, not even in the sporadic way management, marketing, the legal department, or even customers often participate. The best such thin participation can achieve is public acquiescence, not informed consent, since the public, being only a collection or aggregate, can have no will of its own (only so many individual wills). Without a public will, there can be no public consent, informed or otherwise. Among the less happy outcomes of involving the public only late in the process (or not at all) is mass outrage at the result, an expensive redesign, or total abandonment of the project.

What we propose to do here is to assume the definition of public just described and argue for a partial solution to the second problem (the one concerned with tradeoffs). This paper has three parts. The first briefly offers a general argument for public participation, one relying on generally accepted principles of engineering ethics. The second part describes two notable examples of public participation in setting expectations for the future performance of buildings in their communities. The examples demonstrate that large-scale public participation in engineering is practical. The example may also provide a model for thinking about public participation in other engineering contexts. In the third part, we present a public opinion survey to elicit the public's understanding of and expectations for the future seismic performance of new buildings in their communities.

THE GENERAL ARGUMENT FOR PUBLIC PARTICIPATION

We may take it for granted that engineers should always use the best information reasonably available and, insofar as reasonable, seek to improve the stock of useful information available. "Best information reasonably available" is, of course, an elastic term, but, at a minimum, it includes (when relevant): information available in standard engineering reference works, whether paper or electronic; information available from employer, client, or colleagues, whether written, graphic, or oral; and information available from other readily accessible sources. The publications of engineering's standard-writing bodies, whether governmental (such as the GSA), professional (ASCE 7), or independent (ISO), also count—when relevant—as information reasonably available. Would not an engineer who, having such relevant information available and enough time to consult it, knowingly failed to consult it have failed to "uphold …the honor, integrity, and dignity of the engineering profession," as required by ASCE Canon 6 (ASCE 2009, p. 6)?

Note that NCSEA's Tenet 6 is identical except for the insertion of "structural" before "engineer." While all the rules under that Canon (and all the sub-tenets of Tenet 6) are concerned with financial corruption, the language of the Canon (and Tenet) is more general (with the reference to "corruption" slapped on at the end). We therefore think it fair to interpret both Canon and Tenet as concerned with any conduct that might damage the profession's "honor, integrity, and dignity."

To return to our hypothetical engineer, if she merely failed to consult the relevant information because she was unaware of it, would we not say that she should have been aware of it and, if anything went wrong because of her failure to consult it, that she was negligent, at least partially responsible for what went wrong, and therefore an embarrassment to other engineers?

The other half of what we propose to take for granted is that engineers should always, insofar as is reasonable, seek to improve the useful information available. This half may appear too demanding. But a close look will, we think, dispel that appearance. The search for new information is limited to what can be considered reasonable. Anything that makes the search unreasonable—constraints of time, budget, law, skill, or the like—is enough to suspend the requirement. The requirement is limited in another way as well. The information need not be sought just because it can be discovered or even because it might prove intellectually interesting. The information sought must be *useful*—or at least appear likely to be. An engineer who failed to seek to improve the useful information available to engineers, when reasonable to seek it, would have failed to "work for the advancement of the safety, health, and well-being of their communities," as required by ASCE Canon 1.e and NCSEA Tenet 1.e. He would also have failed to satisfy two fundamental principles of engineering; that is, he would have failed first "[to use his] knowledge and skill for the enhancement of human welfare [when he could]" and second "[to strive] to increase the competence of practitioners and the prestige of the engineering profession [when he could]" (ASCE 2009, p. 13).

Yet it must be admitted that the public's participation in everyday engineering seems impractical. Members of the public cannot be present at every design meeting, much less sit beside every engineer as he or she works on a project. There are unlikely to be the several millions of the public willing to volunteer for such work. And, if there were, the cost of providing space for them, the difficulties of preserving business secrets, and so on would undoubtedly be enough to make the undertaking impractical.

Nonetheless, the public can make a substantial contribution at one remove from that ideal of pervasive participation. For example, the public can participate in the writing of the technical standards on which engineers regularly rely. Of course, there are at least five obvious objections even to this more limited public participation. We call them: scale; knowledge; interest-group hijacking; psychology; and better alternatives. Let us consider them in order.

While each is a substantial reason against *some* public participation, they are not, individually or even combined, reason enough to give up public participation altogether.

1. *Scale.* The objection from scale might be put this way: The public must have time to participate in the writing of technical standards, not to mention the resources and motivation to attend meetings that may be far from where they live. If engineering standards numbered in the dozens, or even in the hundreds, we might find enough of the public able and willing to participate. But engineering standards number in the thousands or, depending on how we count them, perhaps even in tens or hundreds of thousands. They concern everything from the size of screw threads to storage of nuclear waste, everything from when boilers should shut down to the location of various sensors in a passenger airplane's fuel tanks. In short, we are talking about instituting a system of participation in engineering on a scale not unlike that of juries in the law courts. The courts can fill their juries only by conscripting citizens and paying them for their time. No one has suggested conscripting the public to participate in engineering work, nor is any legislature likely to enact such conscription.

There is nothing in this objection that is untrue, but the only conclusion to draw is that seeking to involve the public in *all* standard writing is probably impractical. The objection leaves open the question whether the public could be involved in some standard writing more deeply than they are now, especially those standards that most directly affect their health, safety, and welfare. Even a small increase in public participation might make major improvements in those standards. The system of participation need not be perfect to be good.

2. *Knowledge.* The objection from knowledge might be put this way: Engineering standards are technical standards, often stated in terms distant from common language when not stated in equations, mathematical tables, or exotic graphs. Training an engineer only begins with four years of engineering school. After that, there are years of practice, during which the "book learning" of school becomes the "engineering judgment" of practice. Writing technical standards is not a job for newly graduated engineers, or even for engineers five or ten years out of school. To expect the lay public to do what even engineers with five or ten years of experience cannot is absurd.

Again, we need not deny the truth of anything in this objection. We need only point out that it misses the point. The point of bringing in the public is not to provide more engineering judgment but to provide something quite different, the public's insight into what tradeoffs between health, safety, and welfare it might accept or reject. The point of *public* participation is to provide information that the engineers should (and probably would) use if they had it. The difficulty, insofar as there is one, is for the engineers to translate their technical language, equations, and the like, into language the public can understand. While engineers may not be as good at such translation as we would like, it is not something foreign to them. They must explain their work to people from upper management, marketing, the legal department, and the like who are often almost as technically naïve as the public. While public participation will doubtless increase the number of the public who understand more about engineering, the point of public participation is not to turn the public participants into engineers.

There is, we should add, at least one important disanalogy between engineers explaining their work to managers, people in marketing, lawyers, or the like and explaining it to members of the public participating in standard writing, a disanalogy making explanation to the public less demanding. The managers, people in marketing, lawyers, and the like usually have decision-making power. The engineers may need their approval to continue work on a project. The exchange of information that goes on at a meeting with managers, people in marketing, lawyers, or the like typically serves the approval sought. The engineers typically view such a meeting as “jumping through a hoop,” that is, surmounting a barrier to what they are doing, a barrier in which they have no intrinsic interest. The relation between engineers and the public participants in their work would be somewhat different. The engineers are, in principle at least, already committed to serving the public health, safety, and welfare. That, after all, is part of being a good engineer. The problem is knowing in what the public health, safety, and welfare consists. The public is there to help the engineers do what they want to do. Getting the public’s take on what they are doing is not a hoop for engineers to jump through so much as help in defining the target at which they are already trying to aim.

3. *Interest group hijacking.* The objection from interest group hijacking is that “the public” is an abstraction; the people the engineers actually sit down with will not be the public as such, but this realtor, that carpenter, and so on. Every member of the public is also a member of various special interest groups. Indeed, the people most likely to take the time to participate in writing engineering standards, apart from engineers themselves, are those who have a strong special interest in those standards (e.g., those whose business or employment will be affected by a change in a certain standard). What begins with the idealistic notion of public participation is likely to end as the grubby practice of interest-group “lobbying.”

Again, we do not deny the truth of anything in the objection. We merely think this objection—like its predecessors—uses the impossibility of perfect participation to block the good that even far-from-perfect participation can do. We say this for at least three reasons.

First, engineers can usually tell the difference between someone speaking for the public and someone speaking for a special interest. When they realize that a “public member” of their group is actually a “lobbyist,” they are free to downgrade his contribution accordingly. The public members are there to give the engineers insight into how to interpret the public health, safety, and welfare. When a public participant seems to be doing something else, he may be ignored.

Second, the problem identified is most likely to be severe when there is only one member of the public present. The conclusion to be drawn, then, is not that the public should not participate at all but that the public should have several members present, enough to allow the engineers to distinguish between special interests and wider interests. Indeed, the process of selecting public members should seek as much variety among public members as possible. Public participation in standard writing should be thought of as sampling rather than political representation. There should be enough public participants and enough variety in the groups they come from for special interests, whether individual or group, to cancel out, leaving the public interest (or at least something close to it) as the only interest they share.

Third, the problem of hijacking by interest groups is most likely to be serious only once the process of standard writing is nearly over and the implications for special interest have become clear. The seriousness of the hijacking problem can, then, be greatly reduced by bringing in public participants as early in the process as possible—before the process has caught the attention of interest groups (Shafie 2008).

4. *Psychology.* The objection from psychology is that the public interest is often quite different from what the public thinks. Indeed, the public, being an abstraction, does not think at all. It is individuals who think, and many of them are emotional, poorly educated technologically, and indeed not even good at serving their own interests, much less articulating the public interest. Their opinions vary wildly over time and even at one time include patent contradictions. What is proposed here amounts to inviting inmates to advise on how to run the asylum to which they have been committed. The public are in the care of professionals, including engineers, because they are incapable of caring for themselves.

While we regard this statement of the objection as extreme, it nonetheless makes a reasonable point. Not every member of the public is suitable for participation in writing engineering standards. At a minimum, the process of selection should exclude the mad, those who cannot understand the effect of adopting the standards in question, and those unwilling to listen to what others have to say. At a minimum as well, the process should be designed to provide the relevant information, to allow for the exchange of opinion, and to allow time for information and opinion to be weighed. Even sensible people tend to choose badly if the situation in which they must choose denies them relevant information, consultation with others, and time to think. We must take care to design the procedures for public participation in writing engineering standards accordingly.

5. *Better alternatives.* The objection from better alternatives might be put this way: The more we have defended the "good enough" against the perfect, the more the public has in practice become little different from the engineers now on standard-writing bodies. After all, every engineer is, in respect to vulnerability, whether in her own person or in the person of those about whom she cares, little different from other members of the public. She may well be a passenger on a plane for which she is writing maintenance standards or the parent of children who breathe the air for which she is writing standards for carbon particulate level. Why is the engineer's membership in the public not itself enough to provide a reasonable surrogate for the public's more formal participation? All things considered, engineers serving as surrogates for the public, while certainly not ideal, seems close enough to the ideal of public participation to make unprofitable the great trouble of bringing in, training, and accommodating public members strictly so called.

What do we say to this last objection? We agree that sometimes the participation of engineers in the writing of a standard may be enough like the public's participation to make public participants unnecessary. For example, public participation may well be unnecessary when the standards being written have little direct effect on the public (as seems to be the case for the standards regarding screw threads or industrial boilers). On the other hand, when the standards do affect the public more or less directly, and on a large scale, as safety standards for roads or buildings do, the engineers are less likely to be good-enough surrogates. Of course, whether public participation will be worth the trouble for this or that standard seems to be (in part at least) an empirical question, one to be settled by "trial and error" (as many difficult engineering problems are), not by abstract argument. There are nonetheless at least three related reasons to think that public participation in standard writing will sometimes, if not often, be worth the trouble, even allowing that engineers can sometimes be reasonable surrogates for the public.

First, engineers have their own special interests as employees. Most engineers who participate in writing standards of a certain kind will do it not only with their employer's permission, but with their employer paying the expenses. The engineers will participate because they are experts, but that expertise will have developed in an environment likely to bias their judgment in their employer's favor. The standard-writing process usually seeks to defeat that sort of bias by mixing engineers having one bias with engineers having countervailing biases. For example, a specific standard-writing body may mix manufacturers' engineers with engineers from both suppliers of the manufacturers and buyers of the manufacturers' products.

Second, engineers typically serve on standard-writing bodies for a long time, long enough to develop substantial expertise in writing the standards in question. A byproduct of that development of expertise is a certain institutional inertia. Having been personally involved in writing a certain standard, an engineer will, all else equal, be less inclined to revise it than someone who has had no part in writing it. And even if not personally involved in writing the standard in question, an engineer will, all else equal, be less inclined to revise it if he has a long-standing relationship with members of the standard-writing body who were personally involved in writing the standard in question. Public members of a standard-writing body, being less likely to serve for more than a few years, are less likely to suffer from such institutional inertia.

Third, engineers as such share a certain perspective on engineering work. Engineering is a discipline that, like other disciplines, gains its power in part by focusing on some considerations and ignoring others—what one might call microscopic vision (see Davis 1989). Engineering's distinctive focus typically serves the public, which is why engineers are in such demand. But sometimes it does not. So, for example, engineers typically would *not* consider trading safety for beauty in the design of a building. Indeed, engineers typically do not consider beauty at all as a standard for evaluating what they do. The public, on the other hand, seems to treat beauty as constituting part of the public welfare. The public may be mistaken in suggesting a certain trade of safety for beauty, for example, in seismic standards, but the engineers are unlikely even to think about the issue unless they have at least heard the arguments that the public would make for that trade.

Of course, the problem of disciplinary focus may sometimes be overcome by bringing in other disciplines. For example, when engineers have reason to think that they will often need to consider questions of beauty in writing standards for buildings, roads, bridges, or the like, they might add architects, artists, or cultural critics to the standard-writing body. But a particular problem of distinctive focus cannot be overcome in that way unless the problem occurs often enough to be anticipated and the appropriate discipline exists to raise the problem. The public should, all else equal, be present whenever the content of their participation cannot be anticipated or, being anticipated, has no surrogate among existing disciplines. Given how fast technology is changing, the experience upon which engineers rely to anticipate public response must often be out of date. Public participation, whatever else it may do, can act as a sort of safety factor or system back-up, protecting engineering's standard-writing bodies from overlooking considerations that the public now considers important even though it did not even a few years ago.

We conclude that there is no decisive objection to public participation in writing engineering standards. The only questions, difficult ones we admit, are when to have public participation, how much, and how to organize it. The best way to answer such questions is by inventing modes of public participation, trying them, and learning from the experience. We turn now to two experiences of public participation, and a novel survey that elicited the public's expectations for the seismic performance of new code-compliant buildings.

TWO EXPERIENCES OF PUBLIC PARTICIPATION

MOORE, OK

On 20 May 2013, a tornado measuring EF5 on the Enhanced Fujita scale touched down in Moore, Oklahoma, killing 24 people and injuring 377 more in Moore and three surrounding counties. This was the third tornado to strike Moore in 14 years. According to Chris Ramseyer (*oral comm.*, 19 July 2015), who participated in an NSF investigation of the damage, city officials realized they had a political problem and set out to reduce the risk to housing posed by tornadoes. In response to an offer from Ramseyer and his University of Oklahoma colleague Prof. Lisa Holliday to inform the city of their findings, Assistant City Manager Stan Drake asked Ramseyer and Holliday to make recommendations for increased code requirements.

The recommendations were made to a citizen's action committee of approximately 15 people that included four home builders, several city staff, and several interested citizens. Ramseyer and Holliday recommended various detailing requirements, such as wind-resistant garage doors, hurricane clips or framing anchors, continuous plywood bracing, increased roof nailing, and closer spacing of rafters. They offered their evidence, explanations, recommendations, and an estimated cost per square foot for the increased design requirements (about $1 per square foot). The home builders agreed that the cost was in the ballpark. The recommendations were presented again to the city council at a preliminary meeting in February 2014, at which questions from the audience were mostly positive. "Nobody was too worried about the increased cost," Ramseyer recalled. The ordinance came up for a vote by the city council in March 2014, at which the ordinance passed unanimously and became active on 17 April 2014. The ordinance included a requirement that new buildings be designed to a basic wind speed of 135 mph, 3-s gust at 33 ft elevation, 50% higher than the 2009 RBC requirement of 90 mph. With the new ordinance, Moore became the "first city in nation to address tornado impact on homes" (City of Moore 2013, p. 1).

Asked about the public's ability to participate in setting code requirements, Ramseyer advised that, "As long as you present the information in a logical manner, and present the plusses and minuses, the public is very capable of deciding what level of risk they are willing to live with. They chose the 135 mph—we didn't choose that—which is the line between EF2 and EF3. By choosing 135, you've covered 85% of the tornados, and you've covered the bulk of the [area affected by tornados of strength] EF3 and above… they understood that" (C. Ramseyer, *oral comm.*, 19 July 2015).

SAN FRANCISCO COMMUNITY ACTION PLAN FOR SEISMIC SAFETY (CAPSS)

The San Francisco Community Action Plan for Seismic Safety (CAPSS) started in the San Francisco Department of Building Inspection in 1998. CAPSS was a nine-year,

$1 million study to understand, describe, and mitigate San Francisco's earthquake risk. The CAPSS report produced an extensive analysis of potential earthquake impacts as well as community-supported recommendations to mitigate those impacts. In December 2010, Mayor Gavin Newsom formed the Earthquake Safety Implementation Committee (ESIC) under the City Administrator's Office, which created the Earthquake Safety Implementation Program (ESIP) in late 2011. ESIP is a 30-year work plan and timeline implementing the CAPSS.

A notable feature of CAPSS was the public advisory committee: a group of self-selected volunteers—tenants, landlords, small business owners, and other concerned citizens—who met more than 30 times over 2½ years to guide the project. It was the public advisory committee that selected the measures of seismic performance that the engineers involved in CAPSS were asked to estimate. It was also the public advisory committee that reviewed the findings of the CAPSS study, proposed five long-term objectives to guide mitigation actions and priorities, and formulated and approved 17 recommended actions for San Francisco's city government leaders to meet those objectives. As a consequence of the public advisory committee's recommendations, ESIP was approved and has already begun to improve San Francisco's resilience. One of its first actions was to mandate the evaluation and seismic retrofit of a particular class of numerous and highly seismically vulnerable, high-occupancy woodframe residential buildings with weak ground stories. The interested reader is referred to ESIP (n.d.) for more details.

CAPSS also illustrates a limitation to the public's ability to understand probability aspects of risk. The public advisory committee preferred best-estimate performance measures in four discrete scenarios and focused on one scenario, which was neither the biggest nor the smallest of the four. As the deputy project leader, Laura Samant, told Bonstrom et al. (2012), "By eliminating probability, which is a confusing concept for a lot of people, the [risk] becomes way more impactful for the average person. You can imagine: if this happens, this is the result" (p. 4). Despite simplifications, the program was successful, leading among other outcomes to a mandatory retrofit program that, despite high costs to owners and tenants, met with community and city-council approval—a rare outcome that the city's Chief Resilience Officer, Patrick Otellini, attributed largely to the early and ongoing participation and direction from the public advisory committee (Otellini, *oral comm.*, April 2015).

A SURVEY OF PUBLIC EXPECTATIONS FOR EARTHQUAKE PERFORMANCE

We have shown that engineers appear to have an ethical obligation to elicit public preferences and reflect them in seismic design requirements. From the examples of CAPSS and Moore, Oklahoma, one can see that non-engineers are capable of understanding natural-hazard risk and developing policy recommendations to enhance the performance of the buildings on which their lives and livelihoods depend. What can we say in general about the public's expectations for new code-compliant buildings?

In a study of the potential consequences of a large (Mw 7.0) earthquake on the Hayward Fault in the San Francisco Bay Area, and in collaboration with the National Institute of Building Sciences' Multihazard Mitigation Council and others, one of us (Porter) developed and performed a public-opinion survey to address that question. See Porter (2016b) for details. At least one other survey attempted to ascertain the public's confidence in the safety of existing buildings (IAPMO et al. 2012), but this study may represent the first population survey to elicit the public's understanding of how the code measures seismic performance, its quantitative objective, the public's preferences for seismic performance, and its willingness to pay for better performance.

The survey elicited 814 responses from adults in California and in the metropolitan statistical areas (MSAs) of St. Louis, Missouri, and Memphis, Tennessee. (All mentions of those two cities refer to the MSAs, not the city.) The survey excluded building professionals: people employed in construction, structural design, architecture, building trades, building officials, and building inspectors. The survey was performed online by a survey company using a human-subjects research protocol approved by the Institutional Review Board of the University of Colorado Boulder. Survey responses were collected during July 2015. The survey asked the following general questions:

1. Respondent's role or relationship to building codes
2. Current code performance objectives for most new buildings in a large earthquake
3. What the building should code provide
4. Preferred measure of seismic performance
5. Acceptable cost to increase seismic performance
6. How important are the issues raised by the survey
7. Age
8. Gender
9. Race or ethnicity
10. Education
11. Household income

Of 1,506 adults invited to participate in the survey, 814 people completed the survey, 105 were disqualified because of employment in the building industry, and 587 declined to participate. Thus the response rate was approximately 58%: $814/(814 + 587)$. Respondents were approximately evenly divided among building owners, building tenants, and others (people who identified as homeowners but not building owners, for example), plus a small number of elected officials and their staff (approximately 2%; Figure 1).

The survey elicited respondents' understanding of what level of performance the building code currently intends for new buildings in terms of performance in "a large earthquake," and then what they preferred the code to provide. We used a non-technical description rather than a magnitude or other measure that the public would be unlikely to fully understand. Choices were: a new building would be functional after a large earthquake with minimal repairs; occupiable (or habitable) during repairs that might be required to restore the building to full functionality; safe enough that occupants would not be killed, even if the building would not be occupiable after the earthquake ("life safe"); something else; or do not know. Approximately 1 in 4 respondents correctly answered that new buildings were intended to be life safe, and approximately the same fraction felt that that level of performance was appropriate. A larger fraction (1 in 3) thought that the code currently aims for new buildings to be occupiable or functional, but the majority of respondents preferred that level of performance. Most of the balance responded "do not know" (Figures 2 and 3).

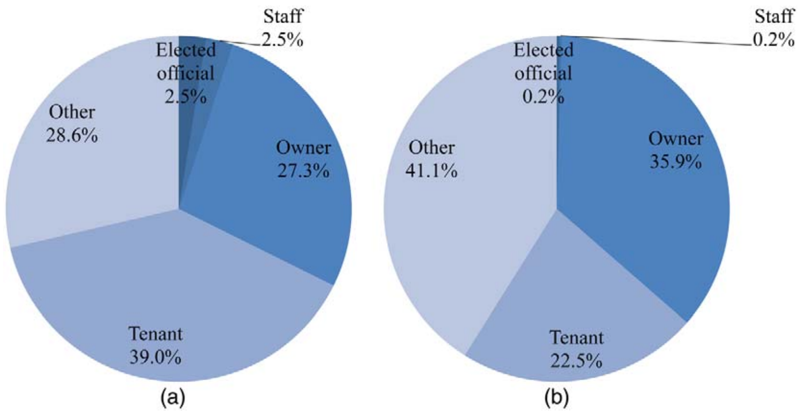

Figure 1. Role or relationship to building codes: (a) California, (b) St Louis and Memphis.

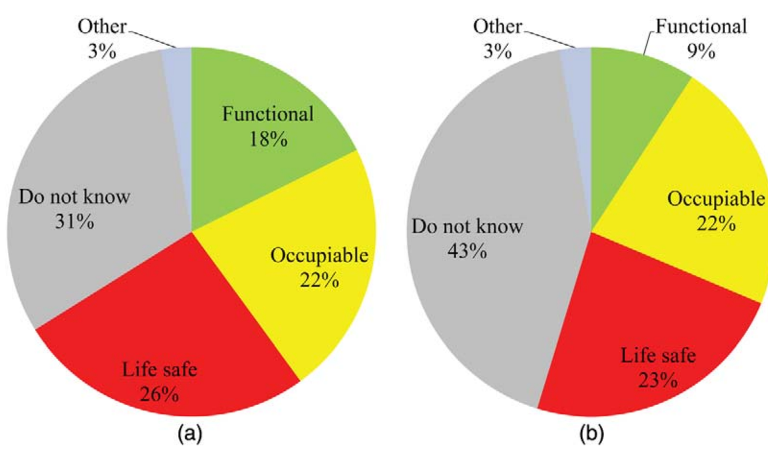

Figure 2. Current code objective: (a) California, (b) St Louis and Memphis.

Of course, better performance comes with a cost, something on the order of $3 per square foot additional construction cost according to various experts and supporting studies (Porter 2016a). The survey asked what the respondent thought that building buyers would be willing to pay for buildings that would most likely be occupiable or functional after the Big One. Options were $0, $1, $3, or $10 per square foot. The options were also stated in terms of the corresponding increase in a monthly mortgage for a single-family home, to make the square-foot costs more easily understood. Most respondents answered $3 or $10, which suggests that the public may be willing to pay for the performance they want.

Is the functional-occupiable-life-safe scale implied here even the right measure of seismic performance? The survey asked which of five building performance measures the

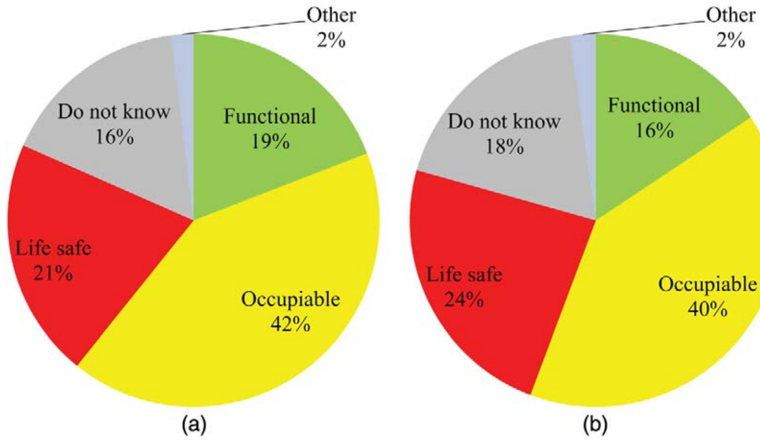

Figure 3. Preferred code objective: (a) California, (b) St Louis and Memphis.

respondents think is of greatest interest to their community: the chance that any given building will collapse in the Big One, the total number of people killed or injured by building damage, the total number of buildings that might collapse, the total number rendered unoccupiable, or the total cost to repair damaged buildings. About 2 in 10 responded that per-building collapse probability is the proper measure. (This is the one actually employed by ASCE 2010.) The plurality of respondents (about 4 in 10) responded that the code should focus on the total number of people killed or injured in a single large earthquake. Equal numbers chose each of the other three options (Figure 5).

The responses to this question do not undermine the earlier ones; they merely show that the public cares first about life safety. The responses do not mean that the public would not prefer a building stock that remains habitable after the Big One. Nor should the reader

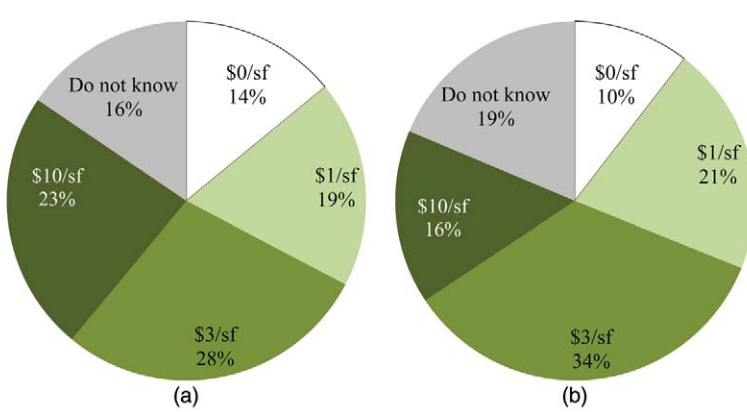

Figure 4. Acceptable cost for occupiable building stock: (a) California, (b) St Louis and Memphis.

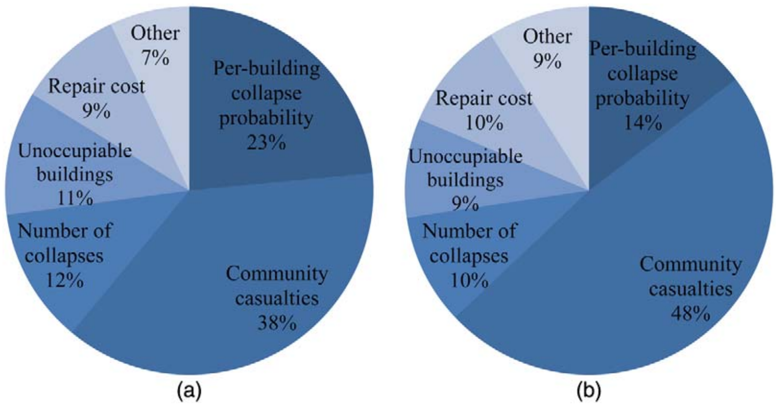

Figure 5. Preferred measure of seismic performance: (a) California, (b) St Louis and Memphis.

conclude that the code's limit on long-term per-building collapse rate equates with the public's apparent preference for measuring performance in total societal casualties in the Big One.

The two measures are not the same. Although building collapse drives deaths and injuries in earthquakes, the per-building probability is blind to the number of simultaneous collapses. The public cares very much about the total simultaneous numbers. In one of the most cited studies on public risk perception, Slovic et al. (1981) show that the leading factor affecting the public's perception of risk is "associated with lack of control, fatal consequences, high catastrophic potential, reactions of dread, inequitable distribution of risks and benefits (including transfer of risks to future generations), and the belief that the risks are increasing and not easily reducible." They refer to Factor 1 as dread risk. It explains why Americans tolerate more than 32,000 deaths per year as a result of automobile accidents and more than 11,000 annual firearm homicides, but spent much of the fall of 2014 in a frenzy of fear over one Ebola-related death in the United States.

Sometimes people express opinions on issues that are not particularly important to them, so the survey asked about that: did the respondent think the future seismic performance of buildings was unimportant, not very important, important, or very important? Approximately 4 in 5 chose important or very important (Figure 6).

If one is to draw any conclusions about what American adults think based on what these 814 respondents said, one must ask how representative respondents are of the larger group. Sample size is important. For a population in excess of 10,000,000 people, the present sample size of 400 for each of the two regions (the first being California, the second being the combination of St. Louis and Memphis) provides a ±5% margin of error with 95% confidence. That is, responses to survey questions in each region are expected to be within 5% of what the population as a whole would say, with 95% confidence. Considering both regions together, the margin is approximately ±3.4%.

That said, online polls tend to reflect the opinions of people who spend time online, and the demographics of the survey does deviate from the population as a whole. Responses

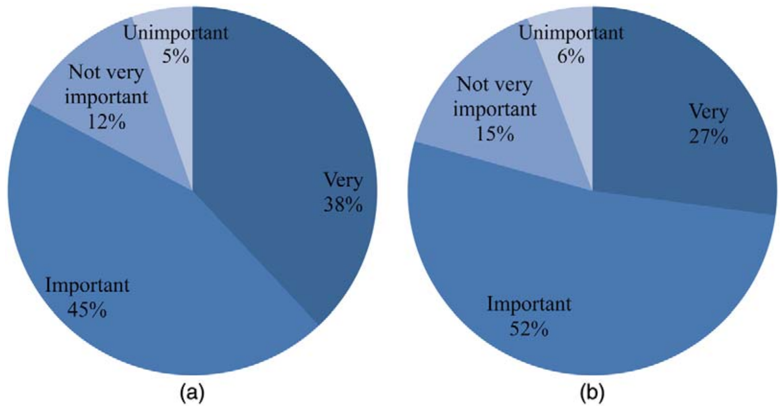

Figure 6. How important are these issues: (a) California, (b) St Louis and Memphis.

included 496 women and 317 men, or 6:4 rather than the approximately 1:1 ratio in the general public. Respondents were generally wealthier than the population: the median annual household income of the California sample was approximately \$84,000, versus \$60,000 reported by the U.S. Census Bureau's (2015) American Community Survey for California households in 2013. Respondents in both regions report more education than the population as a whole: in California, 98% of respondents reported having at least a high school diploma or GED and 58% reported having at least a bachelor's degree, whereas in the California population the figures are 85% and 28%, respectively, as reported by the U.S. Census Bureau (2012) from 2009 statistics. Respondents are also whiter than the population as a whole. So the survey results should be taken with the caveat that respondents may better reflect the preferences of wealthier, whiter, more educated Americans than the general population.

CONCLUSIONS

Seismic provisions of U.S. building codes reflect the experience, judgment, and technical capabilities of building officials and especially structural engineers. Little effort has been made to elicit the public's understanding or preferences for the seismic performance of the building stock. There is reason to believe that the ASCE Code of Ethics requires civil engineers to make a reasonable effort to elicit and reflect the preferences of the public, whose lives and livelihoods are at stake, when setting seismic performance objectives.

The public seems capable and willing to understand the seismic performance of buildings and express its preferences, as suggested by the San Francisco Community Action Plan for Seismic Safety (CAPSS) and the City of Moore, Oklahoma. One of us (Porter) undertook a public survey of adults in two highly seismically active regions of the United States: (1) California and (2) the combination of the two largest metropolitan areas closest to the New Madrid Seismic Zone in the Central United States. With a sample size sufficient to reflect current preferences of the public within ±5% with 95% confidence, the survey implies that the public in both regions prefers better performance than the code is intended to deliver for new buildings. Respondents prefer that buildings remain functional or habitable after a large earthquake, and are willing to pay the $3 per square foot or so additional construction cost needed to achieve such a higher level of performance. Absent contrary survey results in the future, we see no reason to believe that the public willingness to pay that much will erode.

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