SESM 16-01

Not Safe Enough—A Survey of Public Preferences for the Seismic Performance of New Buildings in California and the New Madrid Seismic Zone

By

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Abstract

Earlier disaster planning scenarios developed by the U.S. Geological Survey (USGS), especially the ShakeOut earthquake scenario, suggest that the public is unaware of the life-safety performance objective in U.S. seismic-design standards and may want better building performance. As part of a study of the consequences of a large earthquake in the San Francisco Bay Area, I (through the University of Colorado Boulder) undertook an effort to explore this hypothesis by performing a public survey in California and near the New Madrid Seismic Zone in the Central United States. The scenario examines a hypothetical earthquake with a moment magnitude (M_w) of 7.0 occurring on April 18, 2018, at 4:18 p.m. on the Hayward Fault in the east bay part of the San Francisco Bay area. The survey aimed to determine (1) whether the public understands the current life-safety objective of the building code's seismic-design requirements, (2) what the public prefers in terms of the performance of the building stock in a large earthquake, (3) whether the public would be willing to pay the costs for stronger buildings, and (4) how important the public finds the issue of the seismic performance of buildings. The survey found that, without major regional differences, respondents:

1. Are largely unaware of the life-safety seismic performance objective of American Society of Civil Engineers ASCE 7 and the International Building Code;
2. Are more interested in controlling total number of deaths and injuries in a large earthquake than in controlling per-building collapse probability;
3. Are also interested in more than the total number of casualties and prefer better performance than the code is intended to deliver for new buildings, namely that buildings should remain functional or habitable after a large earthquake (the "Big One" in the language of the survey);
4. Expect better seismic performance than ASCE 7 intends to provide;

5. By a large majority, are willing to pay for greater seismic safety, with the modal response (the most common response) being $3.00 per square foot additional construction cost to achieve such a higher level of performance;
6. Believe that the degree of seismic performance of buildings is important or very important—the response of approximately 80 percent of respondents—even in the Central United States where earthquakes happen much less frequently than in California;
7. Tend to be somewhat more commonly of European descent, wealthier, and more educated than the general public, but regression analyses found no strong trends in either region relating education to acceptable cost for better performance or relating household income to acceptable cost for better performance.

Key implications of the survey indicate that:

1. There is a potential need for writers of seismic-design criteria in ASCE 7 to revisit the seismic-performance objectives for new buildings, considering the public's apparent preferences for better performance.
2. There is a need for better communication with the public about the building code's performance objectives for new buildings.
3. Practical options for stronger buildings are needed that an elected official can select in case they, like respondents here, want more from new buildings than the life-safety performance objective delivers.
4. More narrowly, the study has some implications for the Hayward Fault scenario. First, the study of the potential outcomes of designing stronger buildings addresses a real, measured public preference among Californians.
5. Elected officials in the San Francisco Bay area might be interested in hearing about public preferences for the seismic performance of new buildings.

6. Those same elected officials might be interested in hearing about the costs and benefits of higher design requirements, in light of this study and the damage estimated by the Hayward Fault scenario in general.

Introduction

This work deals with public preferences for the seismic performance of new buildings. Before addressing what the public might want, let us first briefly discuss what the building code presently provides. ASCE 7-10 (American Society of Civil Engineers, 2010) recommends minimum design loads for buildings and other structures, including seismic-design requirements. The 2012 International Building Code (IBC; International Code Council, 2012) adopts ASCE 7-10 by reference, and cities generally adopt the IBC, sometimes with minor modifications. Thus, ASCE 7 tends to control how buildings perform in earthquakes. Oversimplifying somewhat, ASCE 7 helps to ensure that new buildings are designed so that fewer than 1 percent will collapse in earthquakes during the first 50 years of their existence, called their design life. As discussed in Porter (2016), studies by the Federal Emergency Management Agency (FEMA) and National Institute of Standards (NIST) imply that "fewer than 1 percent" means, on an expected-value basis, that about 0.6-percent of buildings will collapse during their design life. ASCE 7 provides various other requirements to control repair costs, but essentially the 0.6-percent goal ensures a reasonable degree of life safety and is commonly referred to as the building code life-safety performance objective.

In Porter (2016), I showed the current building code's life-safety seismic performance objective has a serious unintended consequence—that a magnitude 7.0 earthquake on the Hayward Fault with an Oakland epicenter can impair hundreds of thousands of buildings, potentially displacing a million people or more. In the opinion of a USGS scientist who deals regularly with local governments, and based largely on her experience during the development of the ShakeOut earthquake scenario (Jones and others, 2008), city councils and mayors "absolutely do not know" how a code-compliant building stock designed to meet the life-safety objective will perform in a large earthquake, and are unsatisfied when they do learn of it (Lucile Jones, USGS, oral commun., November 19, 2013). The seismic-design requirements adopted by the building code are written without consulting the public.

The 1927 Uniform Building Code (International Conference of Building Officials, 1927) provided the earliest seismic-design provisions and was based on the experience and judgment of 60 building officials. In the subsequent 90 years, professional engineers and structural engineers (for the most part) have driven the development of seismic-design provisions. Developers of load- and resistance-factor design once called for a profession-wide debate among structural engineers on the proper seismic reliability of new buildings (Ellingwood and others, 1980), but such a debate never took place, let alone a discussion with the public.

Of course, city councils and mayors adopt or adapt model buildings codes such as the IBC on behalf of their community. There is a measure of consent in that adoption, is there not? Suppose city councils' and mayors' ignorance of the life-safety objective only points to a failure to communicate on the part of engineers, code officials, or other building professionals. Better communication could conceivably address that problem. Imagine then an effort by structural engineers and others to explain what the building code does and does not provide. If such an effort were undertaken, then when a city council adopts a model building code, could we not say that well-informed city councils who adopt the IBC would be giving informed consent on behalf of the public to the risk imposed by the code? Would that not solve the problem of local governments' ignorance of the seismic performance of the building stock?

Davis (1991), a philosopher of engineering ethics, argues that if one cannot practically formulate and choose an alternative to a risk, one cannot give informed consent. Whether or not city councilmembers understand the code's life-safety objectives, most cities lack the resources to formulate an alternative to a model code and, therefore, cannot give informed consent. Those cities that cannot formulate and choose an alternative—the elected leaders and their constituents—represent "the public" in the sense meant by the American Society of Civil Engineers' (2006) Canon 1 of its Code of Ethics, which holds that "Engineers shall hold paramount the safety, health and welfare of the public . . ." Being a member of the public in that sense has consequences—Davis (2015) has recently shown that the American Society of Civil Engineers' Code of Ethics implicitly requires engineers to consult the public's preferences when writing building standards for earthquakes. He excludes from "the public" the people who write the building code, such as engineers, building officials, and people who work in the building trades. In this work, I offer what may be the first effort to elicit the public's preferences for the seismic performance of new buildings through a large, rigorous population survey. I conducted the survey (through the University of Colorado Boulder) as part of a study of the consequences of a M_w 7.0 earthquake on the Hayward Fault. The particular earthquake envisioned is one of those modeled using broadband, physics-based methods by Aagaard et al., (2010a, b). In particular, it is their hypothetical rupture of the Hayward Fault north and south segments with an epicenter in Oakland, California. Aagaard et al. (2010a, pg. 2938) refer to it in as "HS + HN G04 HypoO."

Objectives

This report addresses the question, what does the public expect and prefer from new code-compliant buildings in a big earthquake? Would the public be willing to pay to achieve their desired performance objective? It addresses these questions through population surveys in two high-hazard earthquake-prone regions. "High hazard" here means at least seismic-design category D as defined by ASCE 7-10 (American Society of Civil Engineers, 2010; figure 1). The study employs a random-sample survey of adults 18 years or older living in two high-seismic-hazard geographic regions.

There is more than one way to perform a survey; this study uses a web-based survey for efficiency. Web-based surveys have advantages and pitfalls, as discussed by Dillman and others (1998). Potential pitfalls include coverage error (the chance that some groups have no chance of selection), sampling error (differences between responses of a sample and those of the entire population), measurement error (resulting from poorly worded questions), and nonresponse error (the difference between responses received and ones that would have been received from people who declined to respond). Dillman and others (1998) offer a number of recommendations to overcome those pitfalls, as discussed later.

The survey covers two geographic areas to probe for regional differences in public preferences. Those regional differences might reflect different degrees of recent experience with earthquakes, different wealth, or other regional issues.

The two selected geographic regions for the Web-based survey discussed in this report are California, virtually all of which is in seismic-design category D or above, and a part of the New Madrid Seismic Zone in the Central United States. In particular, respondents to represent people in the New Madrid Seismic Zone were recruited from residents of the St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas (MSAs), both of which qualify as high-seismic-hazard areas as defined here.

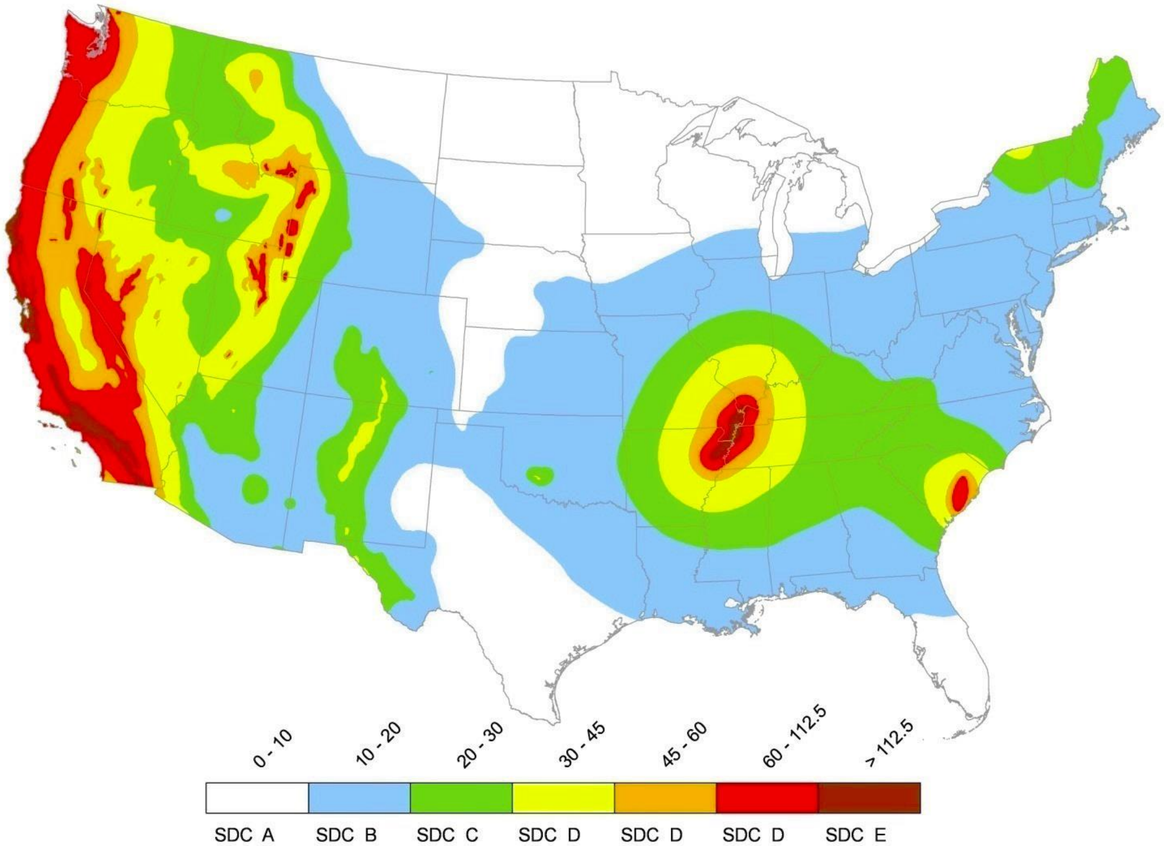


Figure 1. Map of the contiguous United States showing risk-adjusted maximum considered earthquake (MCE_R) motion 1-second spectral response acceleration parameter (S_{M1}) in percent of acceleration due to gravity (*g*) for seismic-design categories (SDC) A–E. Note that most of California and the New Madrid Seismic Zone in the Central United States, the areas examined in the Web-based survey discussed in this report, are in seismic-design category D. (Map from Building Seismic Safety Council, 2009.)

An earlier preliminary survey of 66 Californians suggested that the public was largely unaware of the building code's seismic performance objectives for new, code-compliant buildings; that the public generally wanted more than life-safe performance from ordinary buildings, and that they would be willing to pay $3.00 to $10.00 per square foot more for a code-compliant building stock in which the population could shelter in place after a large earthquake. The preliminary survey constituted a so-called convenience sample because the respondents could be conveniently accessed rather than because they represented a random sample. The preliminary survey also tested the survey instrument, meaning that I personally administered the survey several times and respondents were encouraged to ask questions. None of the questions they asked suggested that the survey was unclear. Furthermore, questions were reviewed by Dr. Liesel Ritchie, a sociologist with expertise in surveys, who expressed the opinion that the language was clear. Data from the preliminary survey are not included here, to ensure that the convenience sample is not mixed with the random sample. See Porter and Davis (2015) for details of the preliminary survey.

At least one other survey has attempted to ascertain the public's confidence in the safety of existing buildings (International Association of Plumbing and Mechanical Officials and others, 2012). Those authors found that "The majority of Americans understands that building codes exist to keep us safe. However, beyond that basic fact their knowledge and appreciation of building codes appears weak. . . . Americans are generally confident that the structures where they live and work have adequate safeguards given the types of natural hazards in their areas." The Urban Institute's (1991) study of the public's willingness to pay for life safety informed later decisions about acceptable cost to avoid statistical injuries and fatalities, such as can be found in Federal Highway Administration (1994). The present report may represent the first population survey to elicit the public's understanding of how the code measures seismic performance, its quantitative objective (that is, numerically, how safe are new buildings), the public's preferences for seismic performance, and its willingness to pay for performance in excess of current code requirements. This study is intended primarily to address willingness to pay for seismic safety of new buildings, a new risk context domain to which one can compare findings in other domains. The survey can also be compared with other methods to assess willingness to pay.

Because the survey was performed by a public university, the University of Colorado Boulder, it satisfies 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 (Office of the Surgeon General, 1966). 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 the University of Colorado's IRB in light of these requirements.

Survey Approach

The survey was administered using an online survey company, SurveyMonkey.com, because of the ease, speed, and low cost of web surveys compared with alternatives such as random-digit dialing. The survey aimed to elicit at least 400 responses from adults 18 years and older throughout the State of California and 400 adults in the Memphis and St. Louis MSAs. As shown later, it had 413 individual responses in California and 401 individual responses in Memphis and St Louis. All mentions of those two cities refer to the MSA, rather than the incorporated city. Because building professions have a significant role in establishing seismic-design requirements, they do not qualify as "the public" in the present context, and so are excluded for the survey. The excluded professions include construction, structural design, architecture, building trades, building officials, and building inspectors.

The sample size of 400 was chosen for each region because, for a population in excess of 10,000,000 people, a sample size of 400 provides a ±5-percent margin of error with 95-percent confidence. That is, responses to survey questions in each region are expected to be within 5 percent of what the population as a whole would say, with 95-percent confidence. Considering both regions together, the margin is approximately ±3.4 percent. (The accuracy of the estimates depends on how representative the sample is of the population; this question is addressed later.)

The large sample size helps to overcome the potential for coverage error. As shown later, responses were received from all major demographic groups (considering gender, income, education, age, race, and ethnicity). Sampling error is inevitable when one cannot survey the entire population, but the large sample size limits the potential error. Measurement error was minimized through the preliminary survey, as previously discussed. Nonresponse error was addressed by keeping the survey brief. As will be shown later, the high response rate limits nonresponse error.

The survey was administered by a survey company according to a human-subjects research protocol approved by the University of Colorado Boulder's IRB on July 2, 2015. Survey responses were collected in July 2015.

The survey asked the following general questions:

1. Do any of the following apply to you? (Asking if a relation exists to building codes)
2. Respondent's role or relation to building codes? (If disqualified)
3. Performance objectives that most new buildings are intended to meet in a large earthquake?
4. What should the building code provide?
5. Preferred measure of seismic performance?
6. Acceptable cost to increase seismic performance?
7. How important are the issues raised by the survey?
8. Age?
9. Gender?
10. Race or ethnicity?
11. Education?
12. Household income?

The report does not document individual survey responses, but rather presents aggregates in the form of pie charts. Respondents took on average 6 minutes to complete the survey.

Respondent Population and Sampling Procedure

The survey aimed to sample at least 400 adults in California and 400 adults in the combination of the Memphis and St Louis metropolitan statistical areas, excluding adults involved in a buildings profession. The survey was administered by SurveyMonkey.com, who offers this explanation of its sampling procedure:

> We take great care to ensure that we have a diverse group of members who are interested in sharing their opinions with you.
>
> When a panelist joins our community of respondents and becomes a SurveyMonkey Contribute member, they fill out a profile. This profile contains demographic questions (gender, age, region, etc.) as well as some other targeting characteristics you might care about (cell phone usage, job type, and more).
>
> Incentive Structure
>
> Each time a SurveyMonkey Contribute member completes an eligible survey, SurveyMonkey makes a contribution to a charity of the member's choice, and the member can choose to enter a sweepstakes.
>
> Recruitment
>
> We recruit Contribute members from a diverse population of 45+ million people who take SurveyMonkey surveys every month. For example, after completing a survey, respondents are redirected to a page that may feature an advertisement for SurveyMonkey Contribute.
>
> SurveyMonkey Contribute panelists come from the United States, the United Kingdom, and Australia. You choose the country you'd like your respondents to come from. If you need respondents from other countries, please contact us.
>
> Although we recruit panelists ages 13 and up, we have the ability to target respondents by age and can target 18 and older.

Sampling Procedure

We email invitations to respondents who match your targeting criteria. Our system selects a random group from the SurveyMonkey Contribute member base who match the demographic targeting criteria you requested.

We use a standard template email notification to notify respondents that they have a new survey to take. It's not possible to customize the invitation email sent by SurveyMonkey Contribute.

Targeting Criteria

We target members based on the information they provide to us in their profile.

The more variables or criteria you target, the more it constricts the population we can use to build your sample. A more constricted sample may slow down the pace at which your survey can complete—or even make it impossible for us to run your survey at all.

Balancing

If you send your survey to a general audience, your results are generally representative of the population you're surveying. We automatically balance results according to census data for age and gender, whereas location tends to balance out naturally. Balancing precision and granularity improves as the number of responses increases.

When you choose specific targeting criteria, your results are no longer representative of the general population because you're purposefully focusing on a particular subset of the population.

(SurveyMonkey, 2015)

Survey Questions and Responses

The survey asked 12 questions to determine the public's preferences for the seismic performance of new buildings. The initial survey question asks whether the respondent is employed in the building industry. Employment in that industry disqualifies the respondent from answering further questions. Incomplete responses are all the people who were invited to take the survey but who declined to begin it (N. Teckman, written commun., July 14, 2015).

Response Rate

The survey was sent to a total of 1,506 potential participants. The response rate is quite high—60 percent of those eligible in California and 56 percent of those eligible in St Louis and Memphis. Here, response rate refers to the ratio of "completed" to the sum of "completed" and "incomplete" responses for example, 413/(413 + 278)=60 percent. The pie charts in figure 2 show the number of people disqualified, number of completed responses, and number of incomplete responses to the following question:

1. Do any of the following apply to you? (Check all that apply.)

- Employed in the construction industry?
- Employed in the structural design industry?
- Employed in the architecture industry?
- Employed in the building-trades industry?
- Employed as a building official or building inspector?
- None of these apply?

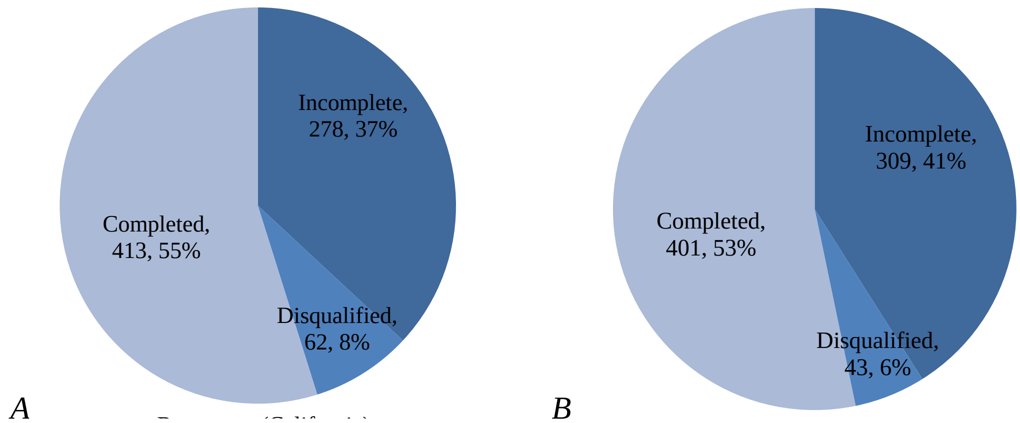


Figure 2. Pie diagrams for survey of the public's preferences for the seismic performance of new buildings showing response rate in (*A*) California and (*B*) in the St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas. Completed, those completing the survey; Incomplete, those who were invited to take the survey but who declined to begin it; Disqualified, those disqualified from the survey. Number and percentage (%) of respondents are shown.

Role or Relation to Building Codes

The pie charts in figure 3 detail the number of people disqualified from responding to the survey. Detailed information about respondent demographics appears below in Respondent Demographics. Figure 3 shows the number and percentage of responses from people disqualified to the following question:

2. What is your role or relation to building codes? Please mark all your roles that apply?

- Local elected official?
- Local government staff who advise local officials on building codes?
- Building owner?
- Building tenant (renter)?
- Other (please specify)?

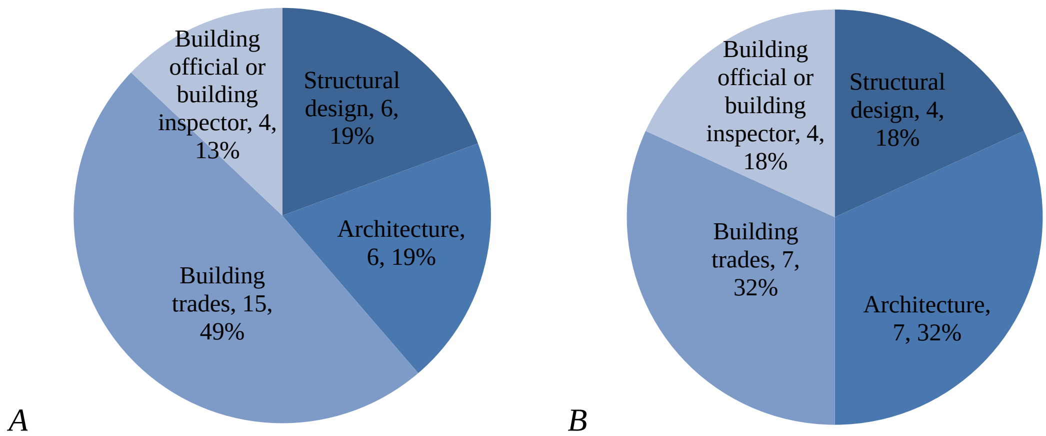


Figure 3. Pie diagrams for survey of the public's preferences for the seismic performance of new buildings showing relation to building codes for people disqualified from participating in the survey in (*A*) California and (*B*) in the St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas. Number and percentage (%) of respondents are shown.

Figure 4 shows the relation of respondents to building codes.(Responses to this and all subsequent questions reflect only completed responses, i.e., from respondents who were qualified for and completed the survey.)

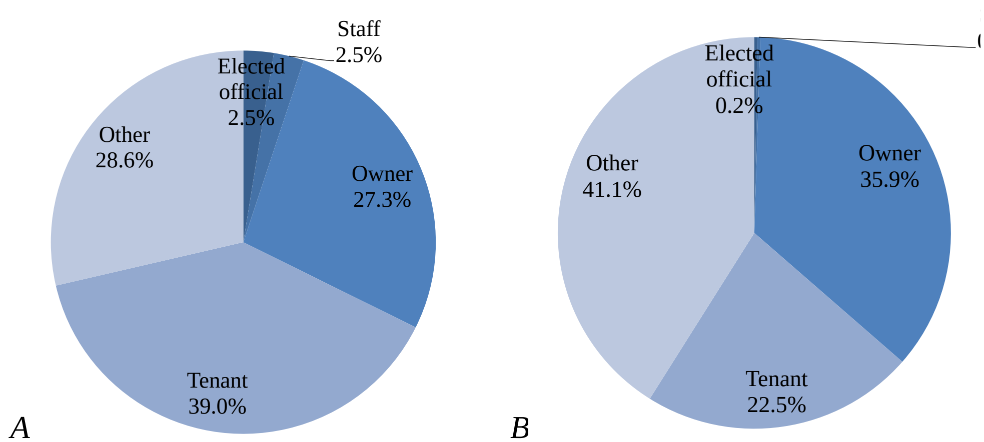


Figure 4. Pie diagrams for survey of the public's preferences for the seismic performance of new buildings showing relation to building codes in (*A*) California and (*B*) in the St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas. Percentage (%) of respondents is shown.

Current and Preferred Code Objectives

Figure 5 shows the percentage of responses to the following question:

3. Although local codes vary, which of these performance objectives do you think most new buildings are intended to meet in a large earthquake? That is, what do you think the current code actually says, not what should it say. Please mark only one answer.

- New buildings will generally be functional after an earthquake, and will require minimal repairs.
- New buildings will generally be occupiable after an earthquake. Although they might require some repairs to be fully functional, the occupants will be able to remain in the building during the repairs.
- New buildings are safe enough that occupants won't be killed, but are not generally intended to be occupiable after the earthquake. That is, a person will be able to exit a building safely, but not necessarily be able to go back in.
- I don't know.

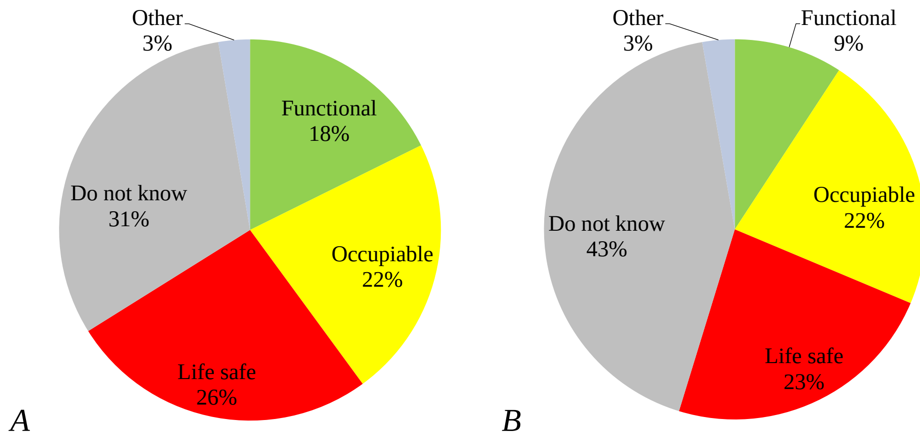


Figure 5. Pie diagrams for survey of the public's preferences for the seismic performance of new buildings showing responses to "Which of these performance objectives do you think most new buildings are intended to meet in a large earthquake?" in (*A*) California and (*B*) in the St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas. Percentage (%) of respondents is shown.

Figure 6 shows the percentage of responses to the following question:

4. What *should* the building code provide? That is, if someone builds a new building in your community and it meets building-code requirements for seismic safety, which one of these would you most prefer the code to ensure? In some of the responses below we use the term "the Big One," by which we mean an earthquake that might be considered a once-in-a-lifetime event. Please mark only one answer.

- New buildings should generally be functional after the Big One, possibly requiring minimal repairs.
- New buildings should generally be occupiable after the Big One. Although they might require some repairs to be fully functional, the occupants should be able to remain in the building during the repairs.

- New buildings should be safe enough that occupants won't be killed, but need not be occupiable after the Big One. That is, a person should be able to exit a building safely, but not necessarily be able to go back in.
- I don't know.

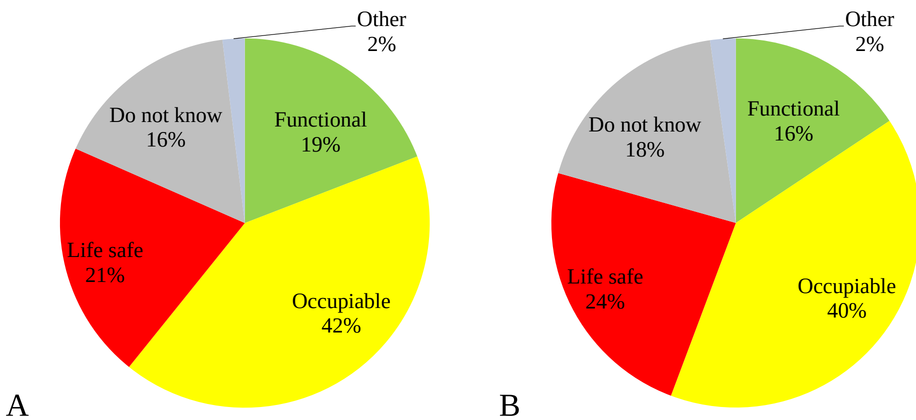


Figure 6. Pie diagrams for survey of the public's preferences for the seismic performance of new buildings showing responses to "If someone builds a new building in your community and it meets building-code requirements for seismic safety, which one of these would you most prefer the code to ensure?" for people in (*A*) California and (*B*) in the St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas. Percentage (%) of respondents is shown.

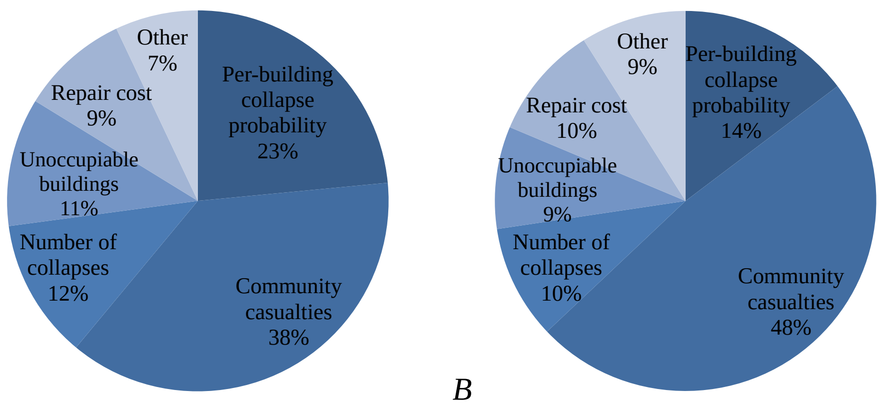
Preferred Performance Measure

Figure 7 shows the percentage of responses to the following question:

5. Which of these building performance measures do you think is of greatest interest to your community? That is, if the building code controlled only one of these measures, which one should it control? Again, "the Big One" here means an earthquake that might be considered a once-in-a-lifetime event. Please mark only one answer.

- The chance that any given building will collapse in the Big One. (Labeled "per-building collapse probability" in the pie chart.)

- The total number of people killed or injured by building damage in your community in the Big One. (Labeled "community casualties.")
- The total number of buildings in your community that might collapse in the Big One. ("Number of collapses" in the pie charts.)
- The number of buildings that would not be occupiable after the Big One. ("Unoccupiable buildings" in the pie charts.)
- The total cost to repair damaged buildings in your community in the Big One.
- Something else or some combination of these (please specify).



A *B*

Figure 7. Pie diagrams for survey of the public's preferences for the seismic performance of new buildings showing responses to "Which of these building performance measures do you think is of greatest interest to your community?" in (*A*) California and (*B*) in the St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas. Percentage (%) of respondents is shown.

Responses to this question beg for some interpretation. The responses suggest that respondents are more interested in controlling total number of deaths and injuries in a large earthquake than in controlling per-building collapse probability. Note well that 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. A large remote earthquake can subject a small town to very strong motion and produce high collapse probability among that small number of buildings. A large earthquake in a metropolitan area can subject a large number of buildings to the same level of motion and the same collapse probability. ASCE 7 does not distinguish between the two cases, but the public does.

The public cares very much about the total simultaneous numbers. In one of the most cited studies on public risk perception, Slovic and others (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. This phenomenon partially 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 (both of which cause at most only a few deaths at a time), but found the 2,996 (nearly simultaneous) deaths in the September 11, 2001, attacks on the United States traumatic enough to launch two wars that ultimately cost more than $1 trillion (Daggett, 2010).

Acceptable Cost for Better Performance

Figure 8 shows the percentage of responses to the following question:

6. This question is intended to obtain information about the tradeoffs between safer buildings and higher initial construction cost (not retrofit cost). Suppose that in the Big One (a once-in-a-lifetime earthquake), up to 1 out of every 5 buildings in your community would collapse or require major repairs, taking a year or more to repair before they could be reoccupied. Also suppose that you could change the building code so that it would reduce that fraction to 1 in 100 buildings or less, but at the cost of higher initial construction costs. What additional cost do you think building buyers should be willing to pay to achieve that end? Please mark only one answer.

- The current risk is already tolerable. No additional cost seems justified.
- Maybe $1 per square foot, which would increase the monthly mortgage for the purchase of a new, typical California house from about $2,000 per month to about $2,010 per month. [In St Louis and Memphis, instead of "...California... $2,000... $2010...." the question says "...St Louis... $750... $758...."]
- Maybe $3 per square foot, which would increase the monthly mortgage for the purchase of a new, typical California house from about $2,000 per month to about $2,030 per month. [In St Louis and Memphis, instead of "...California... $2,000... $2010...." the question says "...St Louis... $750... $770...."]
- Maybe $10 per square foot, which would increase the monthly mortgage for the purchase of a new, typical California house from about $2,000 per month to about $2,100 per month. [In St Louis and Memphis, instead of "...California... $2,000... $2010...." the question says "...St Louis... $750... $824...."]
- I don't know, or you would have to measure the cost some other way (please specify).

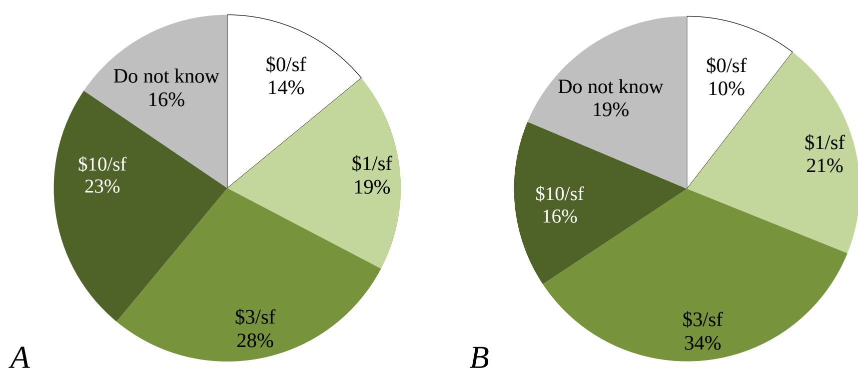


Figure 8. Pie diagrams for survey of the public's preferences for the seismic performance of new buildings showing responses to "What additional cost do you think building buyers should be willing to pay to achieve that end [acceptable tradeoff between safer buildings and higher initial construction cost?]" for people in (*A*) California

and (*B*) in the St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas. Percentage (%) of respondents is shown.

How Important are These Issues?

Figure 9 shows the percentage of responses to the following question:

7. How important are these issues? Please mark only one answer.

- Very important.
- Important.
- Not very important.
- Unimportant.

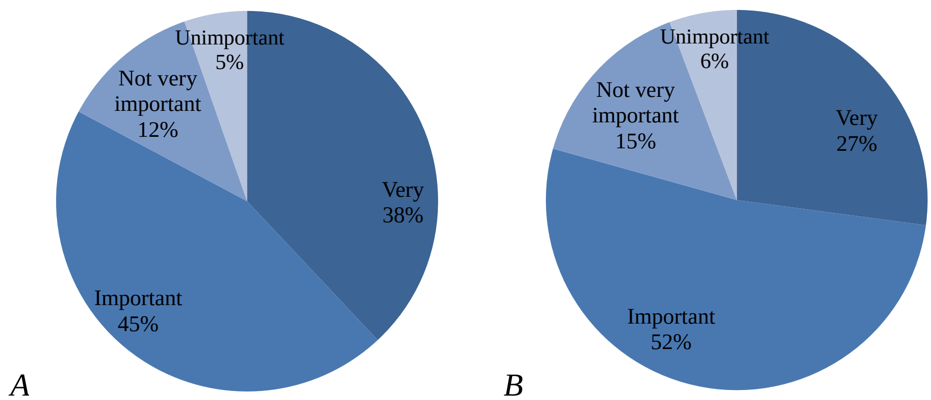


Figure 9. Pie diagrams for survey of the public's preferences for the seismic performance of new buildings showing responses to "How important are these issues?" for people in (*A*) California and (*B*) in the St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas. Percentage (%) of respondents is shown.

Respondent Demographics

Figure 10 shows the percentage of responses to the following question:

8. Age?

- <18
- 18–29

- 30–44
- 45–59
- 60+

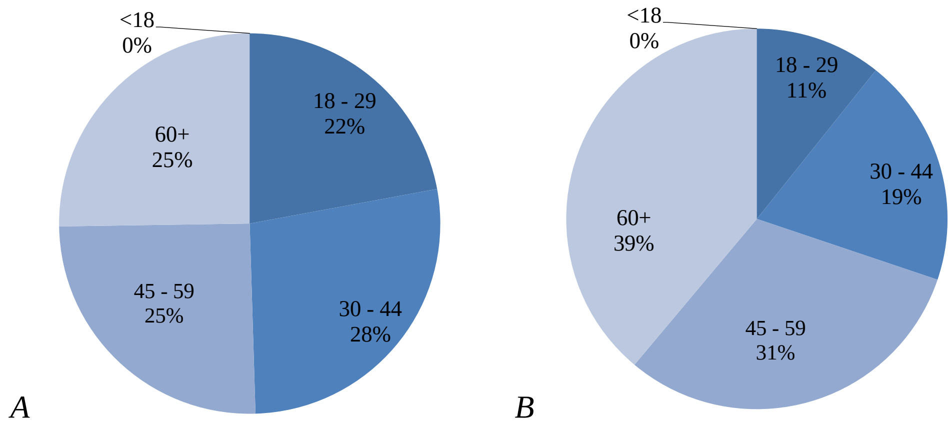


Figure 10. Pie diagrams for survey of the public's preferences for the seismic performance of new buildings showing responses to "[What is your] Age?" for people in (*A*) California and (*B*) in the St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas. Percentage (%) of respondents is shown.

Figure 11 shows the percentage of responses to the following question:

9. Gender?

- Female
- Male

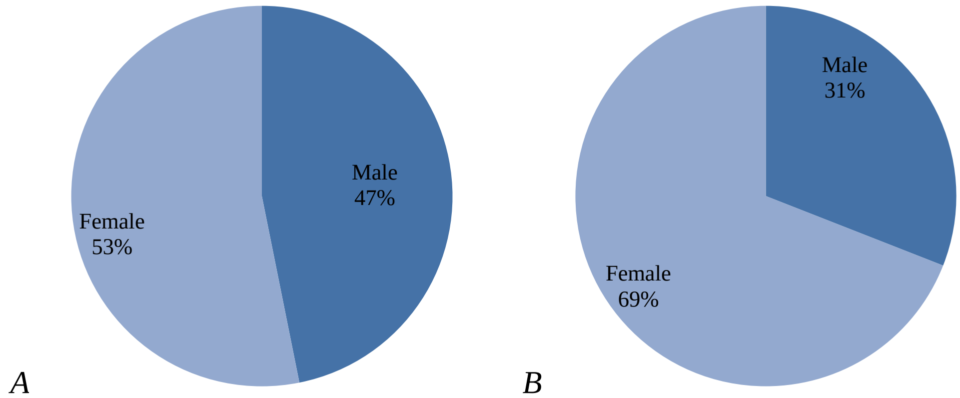


Figure 11. Pie diagrams for survey of the public's preferences for the seismic performance of new buildings showing responses to "[What is your] Gender?" for people in (*A*) California and (*B*) in the St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas. Percentage (%) of respondents is shown.

Figure 12 shows the percentage of responses to the following question:

10. Which of the following best describes your race or ethnicity? (Check all that apply.)

- White/Caucasian
- African American
- Hispanic
- Asian
- Native American
- Pacific Islander
- Other

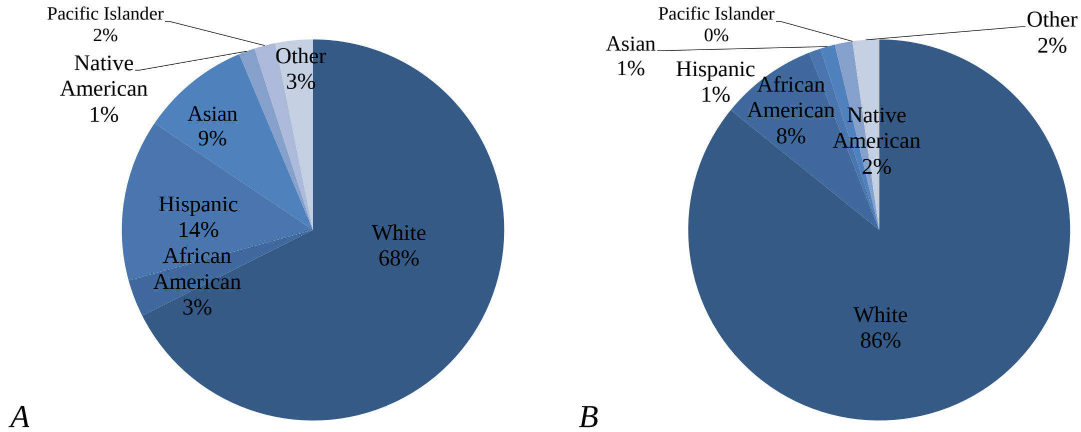


Figure 12. Pie diagrams for survey of the public's preferences for the seismic performance of new buildings showing responses to "Which of the following best describes your race or ethnicity?" for people in (*A*) California and (*B*) in the St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas. Percentage (%) of respondents is shown.

Figure 13 shows the percentage of responses to the following question:

11. What is the highest level of education you have received?

- Less than high school
- High school/GED
- Some college
- 2-year college degree
- 4-year college degree
- Masters degree
- Doctoral degree
- Professional degree (JD, MD)

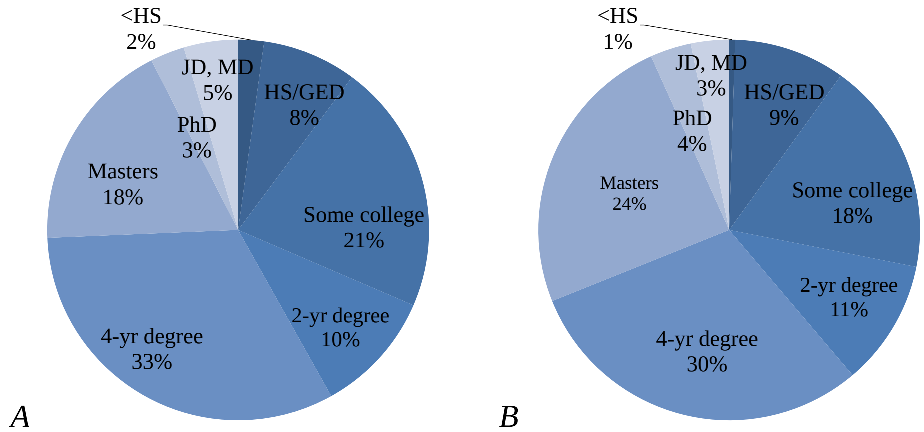


Figure 13. Pie diagrams for survey of the public's preferences for the seismic performance of new buildings showing responses to "What is the highest level of education you have received?" for people in (*A*) California and (*B*) in the St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas. Percentage (%) of respondents is shown. HS/GED, high school degree or General Educational Development certificate; JD, doctor of jurisprudence; MD, doctor of medicine.

Figure 14 shows the percentage of responses to the following question:

12. How much total combined money did all members of your HOUSEHOLD earn last year?

- $0 to $9,999
- $10,000 to $24,999
- $25,000 to $49,999
- $50,000 to $74,999
- $75,000 to $99,999
- $100,000 to $124,999
- $125,000 to $149,999
- $150,000 to $174,999
- $175,000 to $199,999
- $200,000 and up
- Prefer not to answer

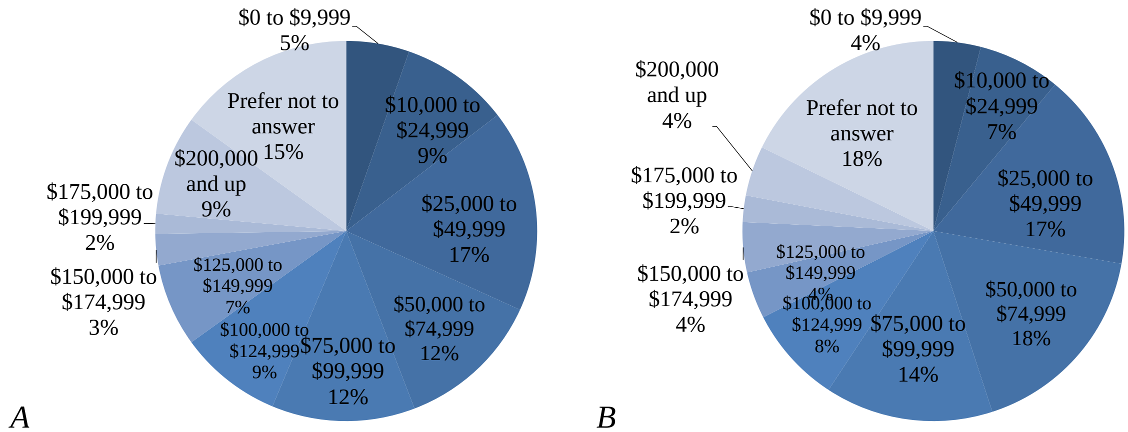


Figure 14. Pie diagrams for survey of the public's preferences for the seismic performance of new buildings showing responses to "How much total combined money did all members of your HOUSEHOLD earn last year?" for people in (*A*) California and (*B*) in the St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas. Percentage (%) of respondents is shown.

Are Respondents Representative of the Population?

This section addresses differences between the demographics of survey respondents and the population of their state or community. If one is to draw any conclusions about what American adults think based on what these respondents said, one must ask how representative respondents are of the larger group. According to SurveyMonkey (2015), respondents "represent a diverse group of people and are reflective of the general population. However, as with most online sampling, respondents have Internet access and voluntarily joined a program to take surveys." Most of the U.S. population regularly uses the Internet—87 percent according to the Pew Research Center (2014). However, not all volunteer to take SurveyMonkey surveys. Respondents receive an incentive to take surveys. "Each time a SurveyMonkey Contribute member completes an eligible survey, SurveyMonkey makes a [$0.50] contribution to a charity of the member's choice, and the member can choose to enter a sweepstakes."

Let us quantify how representative the survey seems to be. The demographics of the survey do deviate from those of the population as a whole. More women than men responded to the survey in both regions. Responses included 496 women and 317 men, or a 6:4 ratio rather than the approximately 1:1 ratio in the general public (fig. 15*A*). Respondents were also generally wealthier than the population (fig. 15*B*). California income data are taken from U.S. Census Bureau's (2015) American Community Survey for California households in 2013. Median household income data for Memphis and St. Louis MSAs in 2010 were taken from U.S. Conference of Mayors (2012).

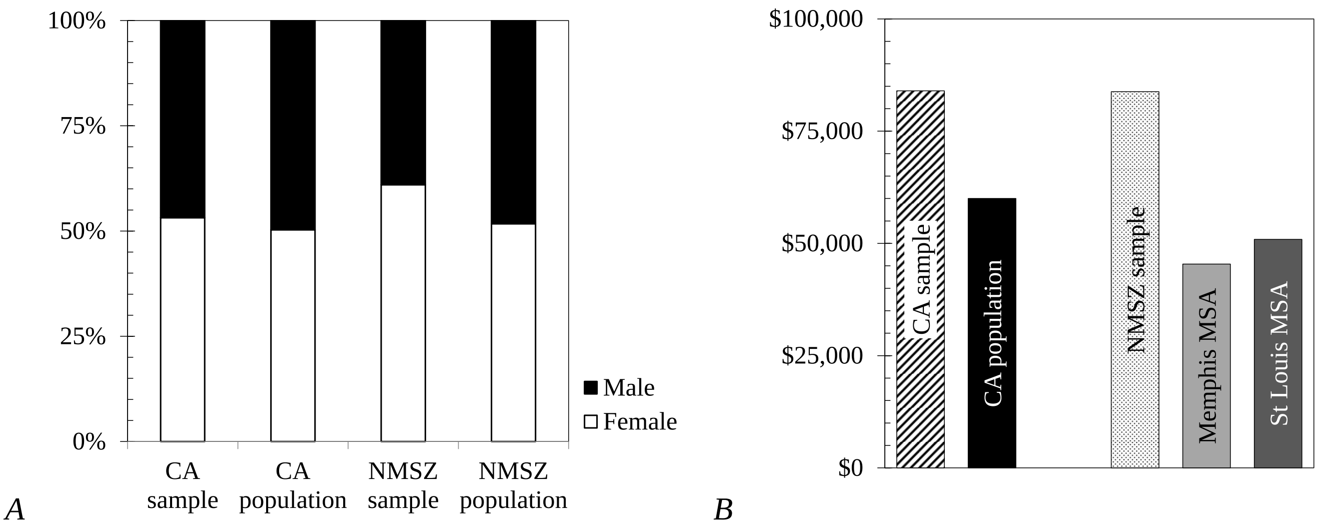


Figure 15. Histograms of respondent (*A*) gender and (*B*) median household income for survey of the public's preferences for the seismic performance of new buildings in the California and St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas (MSA). %, percent; CA, California; NMSZ, New Madrid Seismic Zone.

Respondents in both regions report more education than the population as a whole (fig. 16). Educational attainment of Californians is as of 2009 from U.S. Census Bureau (2012). Memphis MSA data are for 2014 from Memphis Chamber of Commerce (2015). Data for St Louis are for 2012 from University of Missouri St. Louis, Public Policy Research Center (2014).

More respondents are of European (white/Caucasian) descent than the population as a whole (fig. 17). Race and ethnicity data are taken from U.S. Census Bureau (2011).

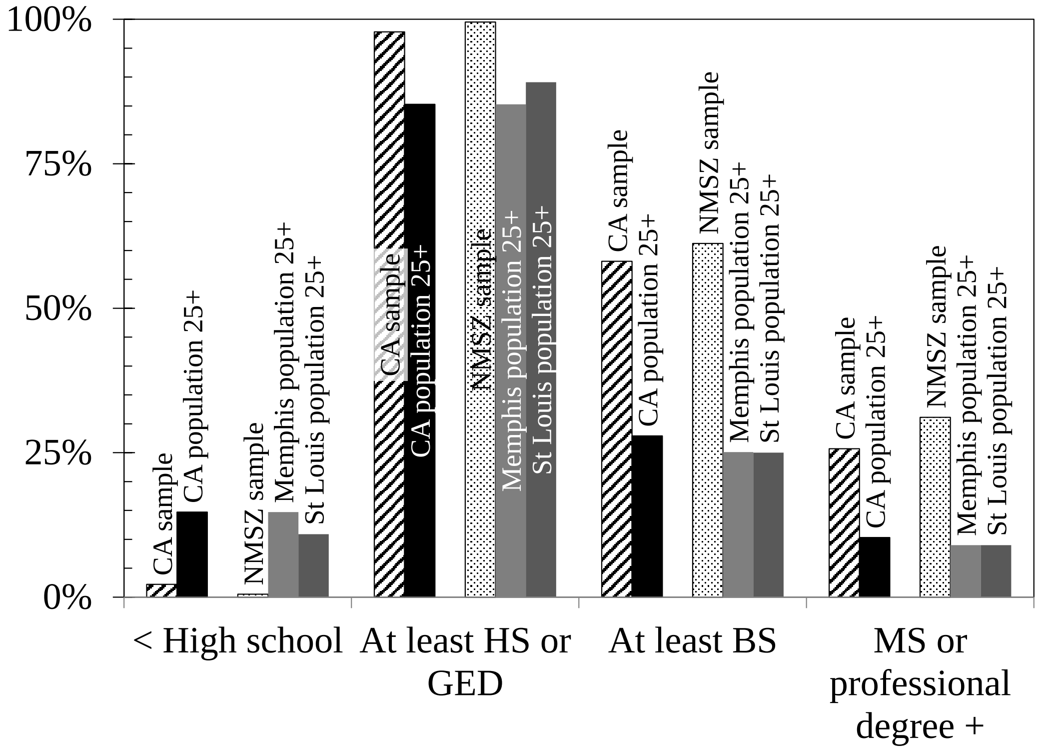


Figure 16. Histogram of respondent education attainment for survey of the public's preferences for the seismic performance of new buildings in the California and St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas (MSA) as compared to relevant populations 25 years and older. %, percent; HS/GED, high school degree or General Educational Development certificate; BS, bachelor's degree; MS, master's degree; CA, California; NMSZ, New Madrid Seismic Zone; <, less than.

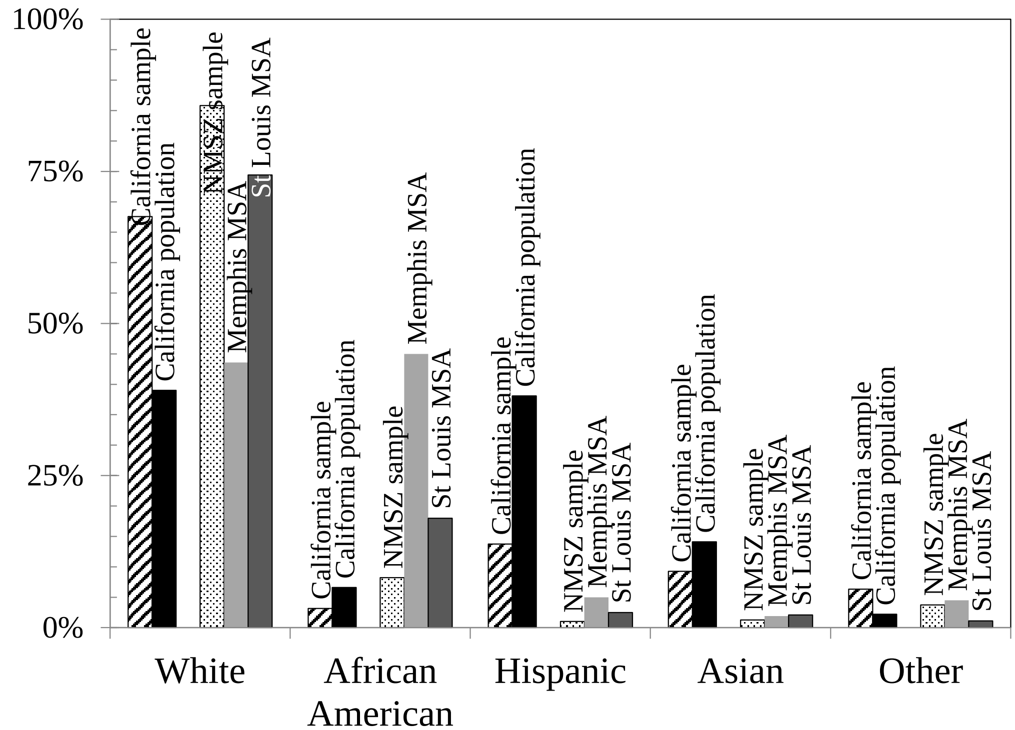


Figure 17. Histogram of respondent race or ethnicity for survey of the public's preferences for the seismic performance of new buildings in the California and St. Louis, Missouri, and Memphis, Tennessee, metropolitan statistical areas (MSA) as compared to relevant populations. %, percent; NMSZ, New Madrid Seismic Zone.

Survey respondents seem to be somewhat more likely to be of European descent than the general population in either region. They are somewhat wealthier and have more education than the general population. These differences may produce a difference between survey participants' responses and those of the general population. The next section tests that hypothesis.

Are Some Groups Willing to Pay More for Better Seismic Performance?

This section examines whether some groups are more willing to pay for better seismic performance than others. Better seismic performance is measured here in terms of building impairment. Suppose that people also equate better seismic performance with more life safety. In such a case, one could compare these survey results with expectations from other methods to estimate willingness to pay for safety. There is a rich literature addressing people's willingness to pay for safety; let us consider just a few sources and compare them what one might predict from them with observations from the present survey.

Needleman (1982) examines several methods to value life safety, including lifetime earning potential (the human capital approach), questionnaires to ascertain people's willingness to pay to reduce their own risk, observed willingness to pay to reduce risk, and observed willingness to take on additional risk for extra pay. He finds that the last method produced the most reliable estimates of people's valuation of small changes in their own risk and that the upper bound of that value is equivalent to 20 times their annual salary per statistical fatality.

In Porter (2002), I briefly review various methods to estimate willingness to pay for more safety in earthquakes, adding to Needleman's list the application of Stanford-style decision analysis, such as proposed by Howard (1980, 1989). In that work I show that, if people behaved as predicted by decision analysis, they should be more willing to pay for life safety in direct proportion to their annual consumption (roughly equivalent to household income), which is consistent with Needleman's finding. I also show that under Howard's decision-analysis framework, older people should be less willing to pay for life safety than younger people, and men should be less willing to pay for life safety than women.

Based on these works, one might suspect that the survey results would exhibit a relation between household income and willingness to pay for better performance or between age and willingness to pay. If either were true, the survey would exhibit a sampling error—a difference between survey responses and the opinions of the broader population. However, a regression analysis of the data from the present survey found no strong trend relating household income and willingness to pay for better building performance. Nor do the survey responses show a relation between education, age, or gender and willingness to pay.

The coefficient of determination, R^2, between individual respondents' household income and acceptable cost for better performance was 0.010 among 350 Californians who provided both quantities.

It was 0.0001 among 303 people from St. Louis and Memphis who provided both quantities. Regression analysis to relate acceptable cost and age in years similarly exhibited low coefficients of determination—0.001 in St. Louis and Memphis, 0.002 in California. Men and women were approximately equally willing to pay for better seismic performance—in St. Louis and Memphis, women were willing to pay 13 percent more on average than men, but in California, men were willing to pay 6 percent more than women.

One might also suppose that years of secondary and postsecondary education would correlate with acceptable cost for better performance. Among 413 Californians who answered both questions, R^2=0.020, and among 170 people from St Louis and Memphis who provided both quantities, R^2=0.022. Nor does one derive higher coefficients of determination from nonlinear regression, fitting polynomials of second, third, or fourth order. (Actually the R^2 values do rise slightly, but the rise has more to do with overfitting than with more information.)

All these coefficients of determination are too low to reject the null hypothesis at the 5-percent significance level, where the null hypothesis is that the correlation coefficient ρ is in fact zero. Put another way, there appears to be no strong relation between education and acceptable cost for better performance, between household income and acceptable cost for better performance, or between respondent age and acceptable cost for better performance.

Conclusions

As part of a study of the unintended consequences of the building code's seismic performance objective, I undertook a public survey in two highly seismically active regions of the United States—one of California adults and another of adults in two metropolitan areas near the New Madrid Seismic Zone in the Central United States, namely the Memphis and St. Louis MSAs. Sample sizes in both regions (413 adults in California and 401 near the New Madrid Seismic Zone) ensure that the results reflect the opinions of the public with ±5-percent margin of error with 95-percent confidence, at least insofar as respondents resemble the public.

The purpose of the survey was to determine whether the public understands the current life-safety objective of the building code's seismic-design requirements; what the public prefers in terms of the performance of the building stock in a large earthquake; whether the public would be willing to pay the cost of stronger buildings; and how important the public finds the issue of the seismic performance of buildings. The survey found that respondents in both regions:

1. Are largely unaware of the life-safety seismic performance objective of ASCE 7 and the International Building Code;
2. Are more interested in controlling total number of deaths and injuries in a large earthquake than in controlling per-building collapse probability;
3. Are also interested in more than the total number of casualties and prefer better performance than the code is intended to deliver for new buildings, namely that buildings should remain functional or habitable after a large earthquake (the "Big One" in the language of the survey);
4. Expect better seismic performance than ASCE 7 intends to provide;
5. By a large majority, are willing to pay for greater seismic safety, with the modal response (the most common response) being $3 per square foot additional construction cost to achieve such a higher level of performance;
6. Believe that the degree of seismic performance of buildings is important or very important—the response of approximately 80 percent of respondents, even in the Central United States where earthquakes happen much less frequently than in California;
7. Are more commonly of European descent, wealthier, and more educated than the general public, but regression analyses found no strong trends in either region relating education to acceptable cost for better performance or relating household income to acceptable cost for better performance.

Study Implications

The survey implies several needs:

1. The Building Seismic Safety Council (which originates many innovations of ASCE 7) could revisit the performance objectives that underlie the seismic-design criteria of ASCE 7, considering (among other issues) the public's preferences as elicited here.
2. Structural engineers could communicate better with elected officials who adopt building codes if they want to reduce the public's apparent misunderstanding of the code's performance objectives for new buildings. Engineers might, for example, create brief (1 page or so) documents about the community-level outcomes of the "Big One," written in plain English, and targeted to elected officials, building owners, urban planning organizations, and other stakeholders among the public (as meant here). Such documents could perhaps be included in an appendix to ASCE 7, or distributed by other means such as by the National Institute of Building Sciences to the United States Conference of Mayors, and the Building Owners and Managers Association International.
3. Practical options are needed that elected officials can select in case they find the code's outcomes unacceptable. For example, an appendix of ASCE 7 or of the International Building Code could explain the costs and benefits of higher design requirements and offer optional adoption language to increase required design strength. For example, the optional language might locally modify the code to require all ordinary buildings (called "risk category II" in ASCE 7-10) to be designed with a seismic importance factor of 1.5.

More narrowly, the study has some implications for the Hayward Fault scenario. It suggests that:

1. The scenario study of the potential outcomes of designing stronger buildings (Porter, 2016) addresses a real, measured public preference among Californians.

2. Elected officials in the San Francisco Bay area might be interested in hearing about public preferences for the seismic performance of new buildings.
3. Those same elected officials might be interested in hearing about the costs and benefits of higher design requirements in light of this study and the damage estimated for the Hayward Fault earthquake scenario.

Limitations and Research Needs

Respondents spanned the domain of age, gender, race and ethnicity, educational attainment, and income of both regions, so there are no significant unrepresented groups. However, this survey only examined two regions. It may be that people in other high-hazard areas have different preferences. It may be that further regression analysis might detect a trend relating other parameters to preferred performance level or to acceptable cost for better performance. Respondents seemed to understand the questions, especially regarding acceptable cost for better performance, but it may be that they would act differently when actually confronted with a real purchasing decision. The present survey only begins to study the public's preferences for the seismic performance of new, code-compliant buildings. More research might better measure any differences between what the code provides and what the public wants. It might be interesting to survey engineers and others involved in the building trades to explore whether and how their preferences differ from those of the public. It would also be interesting to explore the question of preferred performance measure more deeply, such as degree of preference for each option or alternative ways of dealing with probability.

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