USGS Award Number: G13AP00009

Expert Elicitation Workshop on Seismic Vulnerability Estimation
May 8, 2013

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Research supported by the U.S. Geological Survey (USGS), Department of the Interior, under USGS award number G13AP00009. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.

EERI

Expert Elicitation Workshop
(*supported by USGS and GEM*)
5-Star Conference Facility
Oakland City Center

Wednesday, May 8th, 2013

AGENDA

9:45 am	Coffee
10:00 am	Welcome & Introduction of participants: Jay Berger, EERI
10:10 am	Cooke's Method & its application: Dr. Willy Aspinall, University of Bristol, UK/Aspinall & Associates, UK
11:00 am	Collapse Fragility Estimation: Scope, Prelim. Survey Feedback, Guidelines, Building Types and Intensity Measure (IM) Types etc.: Dr. Kishor Jaiswal, USGS/Synergetics Inc.
11:20 am	Building types to be considered in afternoon's exercise: William Holmes, Rutherford & Chekene
12 noon	Working lunch brought in
12:15 pm	Discussion & Consensus: all (experts agree on the building types, their descriptions and the choice of IMs, via consensus)
1:00 pm	Seed Questions (common to all): explanation of each seed item by Kishor Jaiswal and Bill Holmes
2:00 pm	Seed Q&A: all (experts take time to answer all seed items and the responses are collected by Chris Lee, EERI)
2:15 pm	Introduction to Target Questions on Collapse Fragility (Q&A): by Kishor Jaiswal
2:20 pm	Response to Target Questions by Experts: all (experts take time to answer the target questions for their chosen building types and the responses are collected by Chris Lee, EERI)
3:00 pm	Expert Testimony (each expert takes 5 min to provide his/her own perspective on specific factors that he considered while providing judgments on collapse fragilities. No discussion)
4:00 pm	Adjourn (disbursement of honoraria, general feedback from experts on survey process)

Earthquake Engineering Research Institute
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Expert Elicitation Workshop (with support of USGS & GEM)
May 8, 2013

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Soliciting Engineering Judgments on Structural Collapse Fragility of Selected Vulnerable U.S. Construction Types: EERI Oakland Survey

by

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Summary Report:

Following the success of an expert elicitation workshop conducted in Sept 2012 in Lisbon, which was primarily funded by the GEM Foundation, the U.S. Geological Survey (USGS) in early 2013 decided to provide financial assistance to the Earthquake Engineering Research Institute (EERI) to conduct a second expert elicitation exercise. The primary objective of this exercise was to rigorously apply Cooke's procedure for the first time in the field of seismic collapse fragility estimation in order to develop collapse vulnerability relationships for key U.S. construction types. These fragility relationships will eventually be used within the Prompt Assessment of Global Earthquakes for Response (PAGER) system operated by National Earthquake Information Center (NEIC) at Golden Colorado. The Oakland survey was jointly led by the author, and the EERI Special Projects Manager, Ms. Marjorie Greene. In addition, several volunteers and EERI staff members contributed significantly to the success of this exercise (see the Acknowledgment section for details).

The Oakland survey demonstrates the application of Cooke's classical method in soliciting expert judgments for estimating the structural collapse fragility of selected U.S. construction types known to be particularly vulnerable under strong shaking. Cooke's classical method is based on the principle of objective calibration scoring and hypothesis testing in classical statistics (Cooke, 1991). Cooke's approach consists of estimating two separate scores for each individual's contribution and then multiplies them together to get an overall weight for each expert (Figure 1). The mathematical principles behind the method and the detailed analysis of data related to present applications are described in Jaiswal (2014).

In order to apply Cooke's expert elicitation process it was first necessary to identify and recruit leading experts on this topic from academia and industry in the U. S. Names of potential experts were compiled by reaching out to a number of well-known earthquake engineering professionals within the EERI membership and then preparing a preliminary list of experts. The general criteria used for identifying each expert included: a) education/training in the relevant area, b) professional research & structural design experience, c) experience in developing structural models and analyzing structural responses under earthquake loading, and d) international post-earthquake reconnaissance experience. The individuals who were part of the preliminary list met at least three of the above four criteria.

After identifying these experts, a preliminary survey was conducted to identify the core expertise of each expert with respect to specific construction typologies; their experience and expertise in those typologies was solicited, as well as their opinions on a number of parameters such as the preferred ground motion intensity measure to be used for the actual elicitation, the selection of specific structure types among the broad categories, the definition of collapse, and feedback/expectations in terms of their needs prior to the actual elicitation, including how to treat uncertainties.

The preliminary survey was conducted using the SurveyMonkey™ platform. This survey was the most important exercise prior to the actual workshop, since it helped in formulating focused objectives/tasks and ultimately organizing the actual Oakland workshop on May 8th 2013. The preliminary survey questions were independently reviewed by EERI member Mr. William T. Holmes of Rutherford & Chekene in San Francisco.

Prior to the workshop, it was necessary to prepare all the experts for such a novel expert elicitation exercise. Several experts had some previous experience with expert solicitation on the subject matter, but not with Cooke's approach. However, for all, detailed preparatory material was necessary. The preparation exercise (survey) included helping the experts understand the scope of the work and how the method actually works, providing general information through developing and answering frequently asked questions (FAQ) about the methodology, and providing clarifications on the definition of terms used, and the treatment of uncertainties. Several issues were clarified through the preparatory materials ahead of time; however, some concerns remained on topics such as the intensity measure selection for a collapse state, the definition of collapse, and the selection of model building types. These concerns were the topic of much discussion during the Oakland workshop. With the help of several introductory presentations in the morning session of the workshop, these topics were discussed and a consensus was reached among the experts; this dialogue is part of the normal process in Cooke's approach. Despite the consensus, a few experts still had strong opinions about whether a mathematical procedure such as Cooke's method is really the best approach to understand and derive fragility relationships, especially when there still might be some nuances or confusion as to what and how an individual expert might actually think (in terms of specific collapse behavior witnessed from a single or multiple instances during past earthquakes, the specific data/model/experience the expert is grounding his/her judgments upon, and the specific category of construction within a generic class for which he/she is providing fragility parameters). It was acknowledged that future elicitation exercises should only concentrate on fewer construction types, and there should be sufficient time available for discussion on every applicable ingredient of the seismic collapse fragility before final judgments are sought.

Little is known or documented regarding what could be taken as "typical" critical engineering details of older reinforced concrete frame construction (in terms of structural detailing, design and construction practice) that were common in the pre-1940s construction era throughout the country.

Similarly concrete buildings built in a “code era”(post 1940’s to early 1970’s employ a wide variety of lateral and gravity structural systems. Many experts thought that physics-based, nonlinear structural models offer some insights but they possess only limited capability in terms of understanding and predicting the true behavior of these construction types under strong shaking. Thus, an expert elicitation exercise that is more focused on specific aspects of these problems might be a useful way to understand and further fill key data/information gaps. Such exercises may also provide a credible way to understand and help predict the statistical behavior of large numbers of such buildings in future large earthquakes.

Table 1 shows the final model building types that were chosen for the elicitation after the deliberations prior to and during the workshop.

Through the preparatory material, which included seed and target question examples, experts were informed about the Cooke’s process, how the seed questions should be viewed and how such questions influence the scoring process. Cooke's approach consists of estimating two separate scores and then multiplying them together to get the overall weight for each expert. The first score is a ‘statistical accuracy’ measure, called the *calibration score*, which is derived from a logarithmic scoring rule obtained in terms of the true distributional likelihood. The second score is an *information score* that is based on a measure of the sharpness, that is, on the concentration of personal probability distributions in comparison to the uniform (or log-uniform) background distributions. In order to estimate these two types of scores, the experts are given a set of seed questions as part of the expert elicitation process. The seed questionnaire, or quiz, is generally conducted as a controlled exercise (without access to books, reference material, internet or group discussion) with the specific purpose of ascertaining an individual’s ability to make judgments about related yet uncertain values or parameters. Each seed question has a distinct and unambiguous answer, which is not immediately available to the experts.

There were eight seed questions that were given to all the experts who attended the Oakland workshop. Each expert was asked to answer all the common questions in addition to the questions that were specific to his/her expert construction type(s). Contrary to the Lisbon exercise, in the Oakland application specific seed questions were developed (7 to 10 for each category) for new broad construction categories (wood, concrete, and URMs). The objective was to allow individual experts to choose specific categories where they were most comfortable providing engineering judgments. The seed questions pertaining to a broad construction category were designed to reflect experimental test studies, standards/guidelines/design manuals, research studies from literature, and field observations/findings from recent earthquakes. These questions were further revised by the author and reviewed by Mr. William Holmes and Dr. Nico Luco. Both also helped develop several new questions during this process. The selection of the final seed questions was carefully managed by the PI. Figure 2 shows the typical variation in responses to a specific seed question obtained from the pool of experts at the Oakland workshop. As shown in the figure, many experts were able to assess the true answer within the 90th percentile confidence of their estimate for this specific question (provided in terms of 5th, 50th, and 95th percentile bounds); however, several experts (No. 5, 6, 11 and 13) failed to do so, and hence this specific question negatively influenced their overall weighting. Similarly, some of the experts were able to estimate the true answer with a narrower range (No. 4, 9 & 12) than others (No. 2, 3 & 10). There are a number of seed questions on different topics related to seismic collapse fragility observations from past performance, a modelling process, data, and analyses. The Cooke's performance metric thus helps to adjudicate the overall weight that each expert should receive when combining multiple judgments on the collapse fragility for a specific construction type.

To solicit judgments on collapse fragility, an imaginary experiment was developed that helped experts to visualize the problem and provided information about ground motions and other related uncertainties. Each expert then was able to provide his/her best estimate in terms of the median and beta parameter of a lognormal cumulative distribution of collapse probability, or in terms of 5, 10, 25, 50, 75 & 95th percentile estimates of the intensity measure capacity. Because of their familiarity with fragility modelling, most experts preferred the first option. For experts who chose to provide quantiles, the elicited quantiles of the fragility curve provided by each expert were fitted to a lognormal distribution. Figure 3 show a typical response obtained from an anonymous expert on seismic collapse fragility parameters of pre-1940s pure gravity-frame systems with different specifications. In addition to providing the fragility parameters, experts were also asked to provide self-rating in terms of confidence and experience for each of the assessments. These self-assessments were subsequently used as an alternative approach to derive the expert's weight using ATC-13 procedures (ATC 1985), for comparison purposes.

Using the building types identified in Table 1, each expert chose the specific construction types for providing their estimates on seismic collapse fragility, defined in terms of the intensity parameter chosen through consensus. Figure 5 shows a collapse fragility plot for a typical seismically retrofitted unreinforced masonry bearing wall building shown in figure 4. For this construction type, 10 experts provided the collapse fragility parameters, which were then combined (using multiple schemes of weighting) to estimate the derivative fragility curves shown in figure 5. The estimated probability of collapse from an individual expert's judgment was weighted using the weights obtained from specific schemes. Refer to figure 5 in which the brown line with the open square marker symbol shows the curve obtained using equal weighting for all experts, the darker blue line with the filled square marker shows the fragility estimate in terms of a normalized self-weight obtained for each expert, and the light green line with the triangular symbol shows the fragility curve obtained using Cooke's weight. In addition, the figure shows the low and high estimates of the probability of collapse at a given intensity level using dotted blue lines. Thus, these bounds reflect the overall spread across experts in the estimated probability of collapse at each level of intensity measure. It is important to note that this spread is highly dependent upon the expert pool and the true uncertainties could be outside these bounds. We fit the final collapse fragility curves obtained from Cooke's process for each construction type using a lognormal cumulative distribution function and estimated the median and beta parameters of the collapse fragility curves. The lognormal collapse fragility parameters for 25 construction types are also provided here in Table 2 for potential application within the PAGER or any other loss estimation system. Jaiswal (2014) provides a comprehensive summary on the expert survey elicitation procedure and discusses the process employed for deriving seismic collapse fragility functions from both the Lisbon and Oakland workshops.

A number of concerns were expressed by the participants of the Oakland workshop that should be considered in expert elicitation for determination of collapse fragilities. The concerns were mostly related to the fact that available “experts” in the seismic vulnerability of buildings are mostly structural engineers experienced in studying individual buildings with known characteristics. Few have experience considering inventories of model building types described only by material and seimsic force resisting system. This lack of experience or expertise in the specifics of determination of fragilities causes difficulties with development of seed questions used for weighting expert’s judgments using Cooke’s method. It also created concern among the experts that the workshop setting, without the ability to consult literature on the subjects, forced them out of their judgmental “comfort zone.”

Acknowledgments

The author owes a debt of gratitude to Ms. Marjorie Greene of EERI for facilitating both workshops, for her experience, timely engagement, logistical planning, and unconditional support and commitment towards making both expert elicitation efforts successful and memorable. Ms. Greene, David Wald, and Nico Luco helped reviewing this report and providing useful editorial comments. This workshop, as well as the Lisbon workshop in 2012, benefitted greatly from the multiple rounds of discussion and enthusiastic support provided by David Wald, David Perkins, and Nico Luco of the U.S. Geological Survey and Helen Crowley of the GEM Secretariat. Presentations made by Willy Aspinall and Bill Holmes were also critical to setting the stage for further discussions. Prof. Anne Kiremidjian of Stanford University provided scientific advice and technical review for Lisbon workshop, which served as critical input to this workshop. Willy Aspinall, Dimitrios Vamvatsikos, Keith Porter, Bill Holmes, Nico Luco, Abbie Liel, and Siamak Sattar helped the PI in designing some topic seed questions for the Oakland workshop.

The workshop also benefitted from the assistance of EERI graduate intern Christopher Lee, inaddition to project associate Maggie Ortiz and EERI graduate interns Jonathon Tai and Patrick Bassal.

Of course there would be no results to report from the workshop without the generous and enthusiastic support of the workshop participants (experts) who volunteered their time and expertise, asked thoughtful questions, and engaged in lively discussions:

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Aspinall, W. (2008), Expert Judgment Elicitation using the Classical Model and EXCALIBUR, Briefing notes for Seventh Session of the Statistics and Risk Assessment Section's International Expert Advisory Groupon Risk Modeling.

(ATC) Applied Technology Council. 1985. ATC-13, Earthquake Damage Evaluation Data for California, Redwood City, CA, 492 pp.

Cooke, R. M. 1991. *Experts in Uncertainty - Opinion and Subjective Probability in Science*. Environmental Ethics and Science Policy Series. Oxford University Press, New York 10016. ISBN 0-19-506465-8.

Jaiswal, K., Wald, D.J., Perkins, D., Aspinall, W., and Kiremidjian, A. (2013) Estimating structural collapse fragility of generic building typologies using expert judgment, Proc. Of 11th International Conference on Structural Safety and Reliability, June 16-20, New York, USA.

Jaiswal, K. (2014) Soliciting engineering judgments to estimate seismic collapse fragility of generic construction types, U.S.G.S. Open File Report, in prep.

Table 1. Generic U.S. construction types selected for the Oakland expert elicitation exercise.

Structural System (MBT)	Abbreviation	Structure Types			Intensity Parameter
		Type	Short Description	Detailed Description	
W2 (Weak story)	W2-II	II	Seismic Retrofit	Weak first story wood frame (up to 4 stories) with seismic retrofit	S_{MS}
	W2-I	I	No Seismic Retrofit	Weak first story wood frame (up to 4 stories) with inadequate or no seismic design with no seismic retrofit	S_{MS}
URM	URM-III	III	Seismic Retrofit (full)	Unreinforced masonry bearing wall construction (up to 4 stories) with seismic retrofit according to ASCE41 or equivalent	S_{MS}
	URM-II	II	Seismic Retrofit (Parapets, Floor Anchors)	Unreinforced masonry bearing wall construction (up to 4 stories) with partial seismic retrofit such as parapet bracing, floor anchors.	S_{MS}
	URM-I	I	No Seismic Retrofit	Unreinforced masonry bearing wall construction (up to 4 stories) with no seismic retrofit	S_{MS}
C1L (pre-1940s)	C1LPC-II	II	No (Less) Significant Deficiencies	Pre-1940s low rise (1 to 3 stories) pure gravity concrete frames without structural walls with less significant seismic deficiencies	S_{M1}
	C1LPC-I	I	One or More Significant Deficiencies	Pre-1940s low rise (1 to 3 stories) pure gravity concrete frames without structural walls with one or more significant seismic deficiencies	S_{M1}
C1M (pre-1940s)	C1MPC-II	II	No (Less) Significant Deficiencies	Pre-1940s mid rise (4 to 7 stories) pure gravity concrete frames without structural walls with less significant seismic deficiencies	S_{M1}
	C1MPC-I	I	One or More Significant Deficiencies	Pre-1940s mid rise (4 to 7 stories) pure gravity concrete frames without structural walls with one or more significant seismic deficiencies	S_{M1}
C2L (pre-1940s)	C2LPC-II	II	No (Less) Significant Deficiencies	Pre-1940s low rise (1 to 3 stories) gravity concrete frames with structural walls with less significant seismic deficiencies	S_{MS}
	C2LPC-I	I	One or More Significant	Pre-1940s low rise (1 to 3 stories) gravity concrete frames with structural walls with one or more	S_{MS}

			Deficiencies	significant seismic deficiencies	
C2M (pre-1940s)	**C2MPC-II**	II	No (Less) Significant Deficiencies	Pre-1940s mid rise (4 to 7 stories) gravity concrete frames with structural walls with less significant seismic deficiencies	S_{M1}
	C2MPC-I	I	One or More Significant Deficiencies	Pre-1940s mid rise (4 to 7 stories) gravity concrete frames with structural walls with one or more significant seismic deficiencies	S_{M1}
C3L	**C3L-II**	II	No (Less) Significant Deficiencies	Low rise (1 to 3 stories) reinforced concrete frame with infill masonry walls with less significant seismic deficiencies	S_{MS}
	C3L-I	I	One or More Significant Deficiencies	Low rise (1 to 3 stories) reinforced concrete frame with infill masonry walls with one or more significant seismic deficiencies	S_{MS}
C3M	**C3M-II**	II	No (Less) Significant Deficiencies	Mid rise (4 to 7 stories) reinforced concrete frame with infill masonry walls with less significant seismic deficiencies	S_{M1}
	C3M-I	I	One or More Significant Deficiencies	Mid rise (4 to 7 stories) reinforced concrete frame with infill masonry walls with one or more significant seismic deficiencies	S_{M1}
C1L (1940-1980)	**C1LMC-II**	II	No (Less) Significant Deficiencies	1940s-1980s low rise (1 to 3 stories) pure gravity concrete frames without structural walls with less significant seismic deficiencies	S_{M1}
	C1LMC-I	I	One or More Significant Deficiencies	1940s-1980s low rise (1 to 3 stories) pure gravity concrete frames without structural walls with one or more significant seismic deficiencies	S_{M1}
C1M (1940-1980)	**C1MMC-II**	II	No (Less) Significant Deficiencies	1940s-1980s mid rise (4 to 7 stories) pure gravity concrete frames without structural walls with less significant seismic deficiencies	S_{M1}
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	C2LMC-I	I	One or More Significant Deficiencies	1940s-1980s low rise (1 to 3 stories) gravity concrete frames with structural walls with one or more significant seismic deficiencies	S_{MS}
C2M (1940-	**C2MMC-II**	II	No (Less) Significant	1940s-1980s mid rise (4 to 7 stories) gravity concrete frames with structural walls with less significant seismic	S_{M1}

1980)			Deficiencies	deficiencies	
	C2MMC-I	I	One or More Significant Deficiencies	1940s-1980s mid rise (4 to 7 stories) gravity concrete frames with structural walls with one or more significant seismic deficiencies	S_{M1}

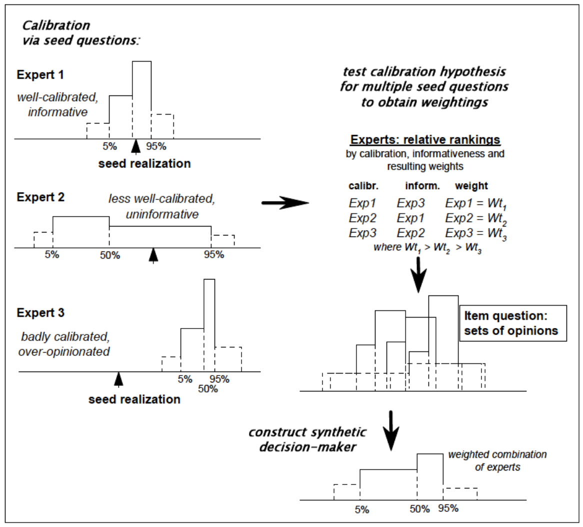

Figure 1. Schematic illustration of typical expert judgment traits, and how these feed into Cooke's procedure to evaluate individual expert weights for pooling responses on seed questions (Aspinall 2008).

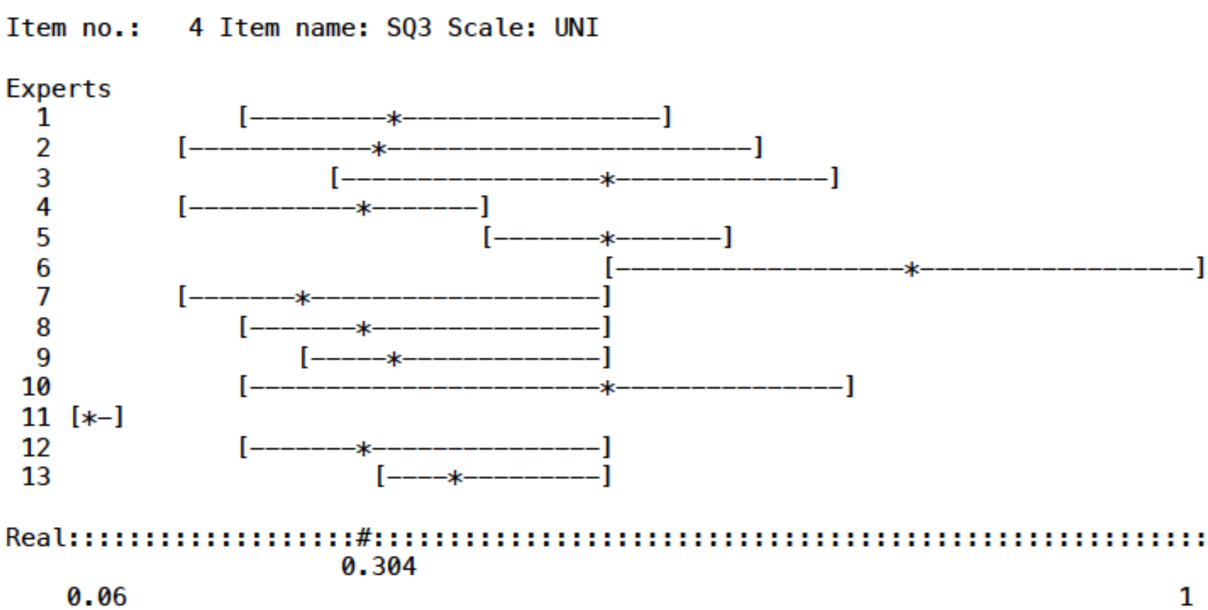

Figure 2. Range graph showing multiple experts' responses to a specific seed question. Many experts were able to assess the true answer for this question within the 90th percentile confidence of their estimate, which positively influenced their overall score.

Print your name	
Building Type	**Old reinforced concrete pure gravity frame (pre-1940s, not designed for earthquake loading.)**

Broad Category	Building type: **Old pure gravity reinforced concrete frame (pre-code)**		Seismic Deficiency of structural System	First Mode Period in sec.	Median estimate of Sa (T, ζ=5%)	Dispersion (β_{total})	Estimate of Spectral acceleration (in g) with 5% damping at T sec. period at % probability of collapse Sa (T, ζ=5%)						Your Confidence in this assignment	Your experience in this assignment
							5	10	25	50	75	95	0 (no) to 10 (highest) scale.	0 (no) to 10 (highest) scale.
Type-I Without structural walls	1 to 3 stories.	Severe deficiency		S_1	0.35	0.9							5	7
		Less-significant deficiency		S_1	0.5	0.8							6	7
	4 to 7 stories.	Severe deficiency		S_1	0.25	0.9							5	7
		Less-significant deficiency		S_1	0.4	0.8							6	7
Type-II With structural walls	1 to 3 stories.	Severe deficiency		S_3	1.0	0.8							5	6
		Less-significant deficiency		S_3	1.5	0.2							6	6
	4 to 7 stories.	Severe deficiency		S_1	0.35	0.8							5	6
		Less-significant deficiency		S_1	0.5	0.7							4	6

Figure 3. A snapshot showing a typical response provided by an anonymous expert to target questions related to pre-1940s reinforced concrete gravity frame construction.

URM-III: Unreinforced masonry bearing wall construction (up to 4 stories) with seismic retrofit according to ASCE41 or equivalent

Figure 4. Typical seismically retrofitted unreinforced bearing wall constructions. Photograph Credit: William T. Holmes

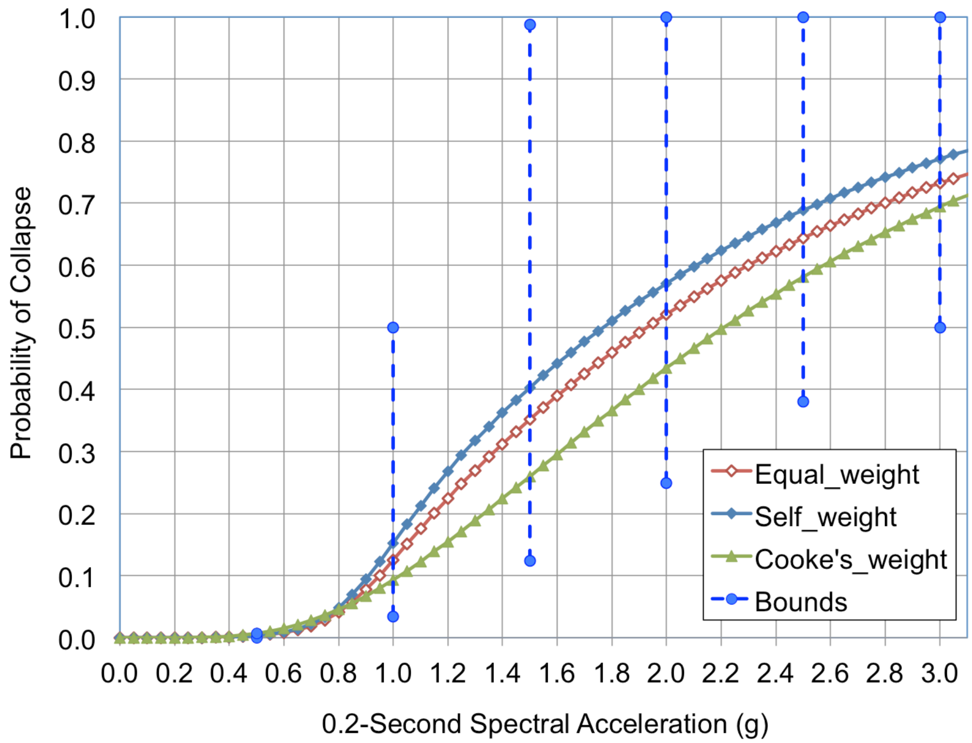

Figure 5. Collapse fragility estimate of seismically retrofitted unreinforced masonry bearing wall construction.

Table 2. Structural Collapse Fragility Models based on Cooke's procedure obtained at the Oakland expert elicitation exercise. Refer to table 1 for details on the model building types. The fragility parameters are expressed in terms of median and beta of cumulative lognormal distribution.

U.S. Model Building Type	Median	Beta	U.S. Model Building Type	Median	Beta
W2-I	S_S = 0.95	0.62	C3L-I	S_S = 0.72	0.97
W2-II	S_S = 2.38	0.54	C3L-II	S_S = 1.30	0.81
URM-I	S_S = 0.51	0.76	C3M-I	S_1 = 0.24	1.00
URM-II	S_S = 0.73	0.76	C3M-II	S_1 = 0.47	0.88
URM-III	S_S = 2.20	0.60	C1LMC-I	S_1 = 0.43	0.85
C1LPC-I	S_1 = 0.29	0.92	C1LMC-II	S_1 = 0.70	0.70
C1LPC-II	S_1 = 0.50	0.82	C1MMC-I	S_1 = 0.37	0.81
C1MPC-I	S_1 = 0.24	0.89	C1MMC-II	S_1 = 0.60	0.72
C1MPC-II	S_1 = 0.43	0.75	C2LMC-I	S_S = 1.38	0.83
C2LPC-I	S_S = 0.82	0.83	C2LMC-II	S_S = 2.00	0.70
C2LPC-II	S_S = 1.50	0.69	C2MMC-I	S_1 = 0.49	0.88
C2MPC-I	S_1 = 0.30	0.89	C2MMC-II	S_1 = 0.87	0.72
C2MPC-II	S_1 = 0.56	0.76	-	-	-