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RESULTS OF A CROSS-DISCIPLINARY SURVEY ON ISOLATION SYSTEMS DECISION MAKING

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ABSTRACT

As part of the NEES TIPS project to facilitate wider implementation of seismic isolation, we conducted an online survey to identify and better understand respondents' overall perspectives on seismic isolation, obstacles to widespread adoption of seismic isolation systems in the United States, and facilitators of adoption. Results indicated that most many people do not believe that they or others are knowledgeable about seismic isolation. Respondents were uncertain about several factors: (1) the technology; (2) the likely risk of earthquake events in their geographic area; (3) the initial and full cycle costs associated with seismic isolation; (4) maintenance of seismically-isolated buildings; and (5) what might happen to a building and its usage after an earthquake event. Respondents favored a number of facilitators to adoption. The top five categories of facilitators were: (1) more education and knowledge-sharing about seismic isolation and its benefits; (2) training and tools for designing and constructing buildings using seismic isolation technology; (3) relaxation of code and other requirements; (4) greater focus on higher performance objectives; and (5) incentives (e.g., insurance).

Introduction

In this paper, we share results from an empirical survey distributed in 2008 to structural engineers, architects, construction managers, building owners/developers/managers, regulatory officials, academics, and others in California, Oregon, Washington, and Utah. The purpose of the survey was to identify and better understand respondents' overall perspectives on seismic isolation, obstacles to widespread adoption of seismic isolation systems in the United States, and facilitators of adoption. The survey was similar to one conducted in Japan following the Kobe earthquake (Clark et al., 2000), which included questions related to the use of buildings designed with seismic isolation; architectural challenges; design, testing, and monitoring practices. A primary catalyst for conducting the survey was the fact that seismic isolation systems have been adopted at a high rate in Japan, in contrast to the low rate of adoption in the United States (Clark et. al., 2000; Higashino & Okamoto, 2006; Kelly & Takhirov, 2001; Mayes 2002). While the United States once led the development and application of seismic isolation, Japan and China now construct more seismically isolated buildings each year than have been constructed in the United States to date (Fujita 2005).

This survey is one component of the larger Network for Earthquake Engineering Simulation (NEES) Tools for Isolation and Protective Systems (TIPS) research project. In NEES

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TIPS, we aim to develop tools and methods to facilitate wider implementation of seismic isolation in the United States, as a means of substantially reducing losses and disruptive societal impacts associated with earthquakes. The objectives of this study are: (1) understand perspectives on seismic isolation in the United States; (2) identify obstacles to widespread adoption of seismic isolation systems in the U.S.; and (3) identify facilitators of adoption.

The Study

Methodology

Beginning in May, 2008, the researchers identified approximately 2,000 individuals who might be knowledgeable about seismic isolation technology in the Western United States using licensing sites, association directories, university websites, firm websites, and government websites. They contacted structural and other engineers, architects, building owner/developers, academics, and regulatory officials through postal mail and e-mail. Potential participants were also recruited through descriptions of the survey in several association newsletters (e.g., EERI). Participants were asked to complete an online survey hosted no later than September, 2008. A paper version of the survey was pre-tested at the 2008 Annual Meeting of EERI in February, 2008. The research was approved by the researchers' Institutional Review Board.

The overall sample size was 257, for an estimated completion rate of 12-15 percent. The majority of the participants were male (n = 212, 92%). The participant pool was well-educated, with 30 percent having bachelor's degrees, 47 percent having master's degrees, and 19 percent having doctorates. Virtually all participants reported being in the construction or design industries (92%). In terms of their primary affiliation, the majority of participants described themselves as consultants (37%), practicing professionals (33%), university employees (9%), or local government employees (7%). The rest of the participants described themselves as federal or state government employees, building developer/owners, retired, or students. In terms of their discipline, more than two-thirds of the sample (68%) identified themselves as structural engineers. Other popular disciplinary choices included architect (7%) and civil engineer (6%).

Survey Results

The impact of seismic isolation knowledge on beliefs and action

When the respondents were asked how knowledgeable they are about seismic isolation technology, 77 percent were at least somewhat knowledgeable about this technology (Table 1).

Table 1. Knowledge of seismic isolation technology.

	Not at all knowledgeable (1)	*(2)*	*Somewhat knowledgeable (3)*	*(4)*	*Very knowledgeable (5)*
Overall N (%)	15 (6%)	42 (17%)	**105 (41%)**	**49 (19%)**	**44 (17%)**
Structural Engineers	5 (3%)	18 (11%)	**64 (40%)**	**35 (22%)**	**37 (23%)**

	Not at all knowledgeable (1)	*(2)*	*Somewhat knowledgeable (3)*	*(4)*	*Very knowledgeable (5)*
Everyone Else	8 (11%)	17 (24%)	**32 (44%)**	**12 (16%)**	**3 (4%)**

Since the survey was voluntary, it is reasonable to expect that many people who felt not at all knowledgeable would have chosen to not complete the survey. Of 77 percent who described themselves as being at least somewhat knowledgeable, many were structural engineers.

Respondents who described themselves as somewhat knowledgeable were asked to indicate how they learned about seismic isolation (Table 2). The three main ways of gaining knowledge were publications by professional associations, seminars/workshops/conferences by professional associations, and personal interaction with engineering consultants or engineering professors. Importantly, the majority of respondents either did not learn about seismic isolation in their university curricula, or believed that they learned more post-graduation through professional associations.

Table 2. Source of knowledge about seismic isolation.

	N (%)
Publications by professional associations	**141 (57%)**
Seminars/workshops/conferences by professional associations	**137 (56%)**
Personal interaction with engineering consultants or engineering professors	**123 (50%)**
Other publications (e.g., periodicals)	105 (43%)
Seminars/workshops/conferences by manufacturers	75 (31%)
University courses (credit or non-credit)	60 (24%)
Seminars/workshops/conferences by your company	57 (23%)
Designed or built at least one building that uses seismic isolation devices	56 (23%)
Company design manuals, guidelines	47 (19%)
Developed or own at least one building that considered seismic isolation devices	31 (13%)
Other	29 (12%)
Served on Code Committee	23 (12%)
Served as a peer reviewer	19 (10%)
Associated with a regulatory agency	19 (10%)

Respondents were asked what they thought was **most important** when making decisions about a building's structural system and seismic risk (Table 3). Avoiding loss of life, avoiding serious injuries and avoiding the total physical loss of a building were the three most important factors to our respondents as a whole. However, when looking at the "very knowledgeable" respondents, we found that the most knowledgeable respondents were more likely to care about all listed possibilities, from avoiding loss of life to minimizing damage to building contents and non-structural elements. The scale used was 1 to 5, where 1 equals "not at all important" and 5 equals "very important."

Table 3. Factors influencing decisions about structural systems and seismic risk.

	N	*Mean*	*Med*	*Std dev*
Avoid loss of life.	**251**	**4.8**	**5.0**	**0.64**
Avoid serious injuries.	**249**	**4.5**	**5.0**	**0.80**
Avoid the total physical loss of a building or facility.	**249**	**3.9**	**4.0**	**0.99**
Use seismic technology that architect and engineers know.	202	3.8	4.0	0.99
Avoid long-term interruption of facility functions or occupancy.	246	3.6	4.0	0.94
Minimize first (initial total design and construction) costs.	202	3.6	4.0	1.06
Minimize cost of mitigating seismic risk.	243	3.5	3.0	0.98
Minimize the potential for financial ruin.	244	3.5	4.0	1.06
Minimize facility repair costs.	246	3.1	3.0	0.90
Assure continuous facility normal-use function or occupancy.	244	3.1	3.0	1.08
Minimize damage to building contents.	246	3.0	3.0	0.95
Minimize damage to building non-structural elements.	247	3.0	3.0	0.98
Maximize flexibility of interior space planning.	200	2.9	3.0	0.97

Benefits of seismic isolation

Our respondents, as a whole, overwhelmingly agreed that seismic isolation has the potential to yield better building performance and that it protects building contents and non-structural elements better than other technologies (Table 4). They also thought that it protects against business interruption better than other technologies. Those respondents who strongly agreed with these statements were more likely to recommend the technology to their clients. The scale used was 1 to 5, where 1 equals “strongly disagree” and 5 equals “Strongly agree.”

Table 4. Benefits of seismic isolation.

Statement	*N*	*Mean*	*Med*	*Std dev*
Better building performance	211	4.3	4.0	0.83
Non-structural elements	196	4.0	4.0	0.95
Business interruption	194	3.9	4.0	0.93

Education

Survey respondents do not believe that many people are educated about seismic isolation (Table 5). If their perceptions of knowledge are accurate, then this likely affects the rate of adoption. On the one hand, engineering firms, regulatory agencies and architectural firms were perceived to be at least somewhat educated about seismic isolation. On the other hand, general contractors, building owners/developers/managers, and the general public were perceived to not be educated on this topic. The scale used was 1 to 5, where 1 equals “not well educated” and 5 equals “very well educated”.

Table 5. Level of perceived education around seismic isolation technology.

	N	*Mean*	*Med*	*Std dev*
Engineering firms	248	3.3	3.0	0.89
Regulatory agencies	244	2.5	3.0	0.95
Architectural firms	248	2.5	2.0	0.92
Insurance firms	229	2.1	2.0	1.01
Construction managers	245	2.0	2.0	0.84
Local government officials	240	2.0	2.0	0.85
General contractors	248	1.9	2.0	0.79
Building owner/ developer/manager	249	1.7	2.0	0.72
The general public	251	1.2	1.0	0.49

Impediments to adoption of seismic isolation

Respondents were asked whether or not certain factors represent an impediment to widespread adoption of seismic isolation technology in the U.S. (Table 6). The top three impediments dealt with the initial costs of seismic isolation. The scale used was 1 to 5, where 1 equals "Not at all" and 5 equals "A great deal." Exploratory factor analysis of the impediments suggested four factors with eigenvalues exceeding 1.0: (1) People – including structural engineers, architects, building owners/developer/managers, and others – not knowing enough about costs vs. benefits of seismic isolation; (2) lack of education for structural engineers or architects; (3) code issues; and (4) seismic isolation perceived to be difficult.

Table 6. Perceived impediments to adoption of seismic isolation.

					Factors & loading			
	N	*Mean*	*Med*	*Std dev*	*(1)*	*(2)*	*(3)*	*(4)*
Developers first costs	**230**	**4.3**	**5.0**	**0.93**	.61			
Building owners first costs	**233**	**4.3**	**4.0**	**0.85**	.56			
First costs	**233**	**3.9**	**4.0**	**1.04**				
Hands-on experience	228	3.9	4.0	1.04	.57			
Business owners unfamiliar	230	3.8	4.0	0.95	.70			
Building code complex	182	3.8	4.0	1.08			.58	
Built to code	231	3.8	4.0	1.14	.57			
Benefits vs. costs	224	3.7	4.0	0.92	.59			
Lack of major earthquakes	231	3.6	4.0	1.16				
Insufficient information	227	3.5	4.0	1.16				
Building code conservative	209	3.3	3.0	1.05			.56	
Architects university courses	214	3.1	3.0	1.09		.65		
Engineers university courses	219	3.1	3.0	1.12		.76		
Designing is difficult	221	3.1	3.0	0.97				.50
Negative architectural impacts	219	2.4	2.0	1.01				

The effect of cost

As noted in Clark et al. (2000), new technologies face resistance until they are perceived to provide improved performance and/or greater reliability at a cost similar to current approaches.
Cost is commonly believed to be a primary driving factor in why building owners/developers choose not to use seismic isolation. Our results agree somewhat with this common belief about the effects of cost on adoption. Survey respondents agreed that the three largest impediments to widespread adoption of seismic isolation technology involved the initial costs of seismic isolation (Table 6). Despite their belief that initial costs were an obstacle to adoption, many survey respondents were simultaneously more willing to accept higher initial cost premiums because they believe that seismic isolation has the potential to yield better building performance. In brief, while initial costs may be higher, costs over the life of the building are not expected to be higher. In addition, we found that respondents who believe that buildings should perform "better than code" are more willing to pay higher cost premiums for the anticipated higher performance of seismic isolation technology.

When asked what they considered to be an acceptable initial total design and construction cost premium associated with the use of seismic isolation, the most common premiums selected were 5 or 10 percent (range: 0-20 percent).

Factors contributing to the adoption of seismic isolation

Respondents were then asked whether certain factors would contribute to greater adoption of seismic isolation technology for buildings in the United States (Table 7). Insurance incentives, development of catalogs of "prequalified devices" for use in standard structures, and benefit-cost analyses were the top three reasons given by respondents. The relaxation of certain restrictions and requirements were the least important factors thought to contribute to the adoption of this technology. The scale used was 1 to 5, where 1 equals "Not at all" and 5 equals "A great deal".

Table 7. Factors contributing to the adoption of seismic isolation

					Factors and loading				
Statement	*N*	*Mean*	*Med*	*Std dev*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Insurance incentives	**214**	**4.4**	**5.0**	**0.75**					**.78**
Pre-qualified devices	**214**	**4.0**	**4.0**	**0.97**		**.66**			
Operational after a seismic event	**215**	**3.9**	**4.0**	**0.87**	**.86**				
Life cycle cost reductions	213	3.9	4.0	0.93	.84				
Building Rating System	208	3.9	4.0	1.09					.77
Step-by-step guidelines	210	3.80	4.0	1.05		.76			

					Factors and loading				
Statement	*N*	*Mean*	*Med*	*Std dev*	*(1)*	*(2)*	*(3)*	*(4)*	*(5)*
Regulatory agencies.	167	3.8	4.0	1.03				.59	
Increased promotion	213	3.8	4.0	0.97	.68				
Adopt JSSI	208	3.70	4.0	1.03	.60				
Computer-based tool	210	3.7	4.0	0.97		.67			
Uniform Building Code	167	3.7	4.0	1.16					
Structural analysis software	207	3.6	4.0	1.05		.68			
Short courses	213	3.5	4.0	1.06		.73			
More emphasis	211	3.5	3.0	1.02	.50				
Life safety performance	157	3.3	3.0	1.13				.62	
Full-scale testing	203	3.3	3.0	1.16				.77	
Removal of requirements	201	3.1	3.0	1.26			.71		
Equivalent Lateral Force Method.	150	2.9	3.0	1.11			.63		
QA/QC requirements	201	2.7	3.0	1.22			.79		
Isolation plane	188	2.7	3.0	1.12			.78		

Exploratory factor analysis of the impediments suggested five factors with eigenvalues exceeding 1.0: (1) More education and knowledge-sharing about seismic isolation and its benefits; (2) training and tools for designing and constructing buildings using seismic isolation technology; (3) relaxation of code and other requirements; (4) greater focus on higher performance objectives; and (5) incentives (e.g., insurance).

Recommending seismic isolation

When asked whether or not they would recommend the use of seismic isolation technology to their clients, 37% of respondents answered “Yes” and 63% of respondents answered “No.” Who is less likely to recommend seismic isolation?

- Respondents who that thought a majority of the public believe that buildings “built to code” will be operational after an earthquake.
- Respondents who believed that there are not enough architect/engineering firms with hands-on experience with seismic isolation
- Respondents who believed that the use of this technology is difficult.
- Respondents who agreed that difficulty and time are increased with seismic isolation technology.

Respondents who did not recommend seismic isolation technology were more likely to advocate emphasis on seismic isolation technology in architecture and/or engineering university courses. They were also likely to believe that clear step-by-step guidelines would increase adoption rates. They were more likely to believe that improved production structural analysis software for analyzing structures including isolators and other protective technology would increase adoption rates. Finally, they wanted further evidence of effectiveness in the form of full-scale testing or experimental research to address specific technical issues.

Those who recommended seismic isolation technology were more likely to favor short courses (and specialty certificates) on protective system technologies. They were less likely to believe that development of catalogs of "pre-qualified devices" for use in standard structures, eliminating the need for project-specific prototype tests would increase adoption rates. They were more willing to join a promotional society. Finally, they were more likely to advocate policies and legislation requiring higher performance objective buildings.

Discussion and Recommendations

This research focused on seismic isolation technology. To that end, while some of the results and recommendations may apply to other technologies, readers are cautioned not to exceed the boundaries of this research when considering the recommendations.

Seismic isolation technology has not been adopted at a high rate in the United States. While there are potentially many explanations for the lack of adoption, one highly probable explanation is that relatively few structural engineers, architects, and building owner/developers are familiar with the technology and its benefits (Table 1 and Table 5). (It seems reasonable to assume that a fair number of potential survey respondents "self-selected" themselves out of the pool because they did not feel they were sufficiently knowledgeable about seismic isolation technology to answer a survey on it.) The survey results suggest that seismic isolation technology is not a common component in structural engineering curricula, and that many people learn about seismic isolation technology through professional associations.

The perceived cost of seismic isolation technology appears to be a serious impediment to widespread adoption. Whether the full cycle costs of seismic isolation technology are lower than the fill cycle costs of other technologies cannot be discerned from this research. What can be discerned is a strong perception by those less familiar with seismic isolation technology that its first costs keep structural engineers, architects, and building owner/developers from considering seismic isolation technology as a viable approach. Seismic isolation advocates must not cling to arguments in which full cycle costs for seismic isolation technology are less than the costs for other technologies, while disregarding the very real possibility that initial costs for seismic isolation technology exceed the initial costs for other technologies. Owner/developers care about both initial and full cycle costs. Both must be as low as possible to secure owner/developer interest.

Determining what will best encourage greater adoption of seismic isolation technology is no easy task. The survey suggests five possibilities. First, those in a position to make decisions need to be better educated about seismic isolation and its benefits. Second, seismic isolation advocates need to create and disseminate accessible and affordable training and tools for designing and constructing buildings using seismic isolation technology. Third, relevant codes should be reviewed and possibly altered in the face of more than two decades worth of seismic isolation building in the United States. Fourth, seismic isolation technology ought to be promoted as consistent with and supportive of a greater focus on higher performance objectives.

Finally, building owner/developers might be more inclined to consider seismic isolation technology if there were additional incentives (e.g., insurance).

Thus, the survey results support seven recommendations:

1. Universities should consider including more information on seismic isolation in their curricula
2. Professional associations should be promoted as a critical source for disseminating information on seismic isolation.
3. Seismic isolation advocates must demonstrate effectively that the cost-benefit ratio for isolation technology is preferable to the ratios associated with other technologies.
4. Seismic isolation advocates should undertake a campaign to communicate the benefits of seismic isolation technology (including its consonance with higher performance objectives) to the general public, structural engineers, architects, building owner/developers and other relevant stakeholders.
5. Seismic isolation advocates need to disseminate more accessible and affordable seismic isolation training and tools.
6. Relevant codes should be reviewed for potential changes that would ease the use of seismic isolation technology without eliminating appropriate safeguards.
7. Seismic isolation advocates should explore what the insurance industry would require (e.g., data) to provide incentives for seismic isolation technology usage.

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