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A CRITICAL EXAMINATION OF DESIGN REVIEW FOR SEISMIC ISOLATED BUILDINGS

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ABSTRACT

As part of the NEES TIPS project to facilitate wider implementation of seismic isolation, we conducted a telephone survey to determine design professionals' experiences and opinions of the design review process for seismic isolated buildings. Participants agreed that the review process is beneficial in concept, but the benefit can sometimes be obscured by poor implementation. Best practice recommendations include 1) the review team should be organized and the review process should be planned at the onset of design, and 2) all parties should mutually agree on a scope of review that avoids unnecessary expansion and a level of detail that is preferably high-level.

Introduction

Structural design review is a verification of the validity of the structural design by a party independent of the engineer of record (Sharpe 1990, ACEC 2000). While practiced in some form in European countries for several decades, structural design review has emerged in the United States more recently as a response to the increasingly complex nature of the design process (Bell and Roberge 1994). Following a number of notorious and arguably preventable structural failures in the 1970's and 1980's (e.g. Petroski 1985), several groups independently concluded the need for design review as a means of safeguarding the built environment against unnecessary disaster (e.g. Gross 1986, Bell et. al. 1989). To promote the concept and facilitate successful implementation, several national and local organizations developed suggested guidelines for carrying out project design reviews. Published guidelines include those by Coalition of American Structural Engineers (CASE 1992), American Consulting Engineers Council in conjunction with American Society of Structural Engineers (ACEC/ASCE 1990, ACEC 2000), and Structural Engineers Association of Northern California (SEAONC 1993).

To accompany philosophical discussions and guidelines, prescriptive requirements mandating structural design review for specific circumstances began to emerge. Leaders to adopt formal requirements for design review included the city of Boston and the states of Massachusetts and Connecticut (Bell and Roberge 1994, Barnes 1995). In adopting the tentative

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requirements for seismic isolated structures published by Structural Engineers Association of California (SEAOC 1989) as an appendix, the 1991 Uniform Building Code (ICBO 1991) became the first wider regional/national code to require design review for any building structure. These original provisions governing design review, developed at a time when seismic isolation was in its infancy, have remained essentially unchanged over the past two decades. Recently, code specifications for buildings with supplementary damping introduced into ASCE-7 (ASCE 2005), based on FEMA 356 (ASCE 2000) and FEMA 450 (BSSC 2003), also include provisions for design review.

While structural design review is recognized to be beneficial in concept, its implementation by practicing professionals has not been seamless. Engineers have been slow to warm to the concept, and dislike having their work reviewed (Sharpe 1990, Mayes 2002). Furthermore, some reviewers have been perceived to overstep the objectives of design review.

In this study, we critically examine the current implementation of design review of seismic isolated buildings in professional practice. Examination of design review is one component of the larger Network for Earthquake Engineering Simulation (NEES) Tools for Isolation and Protective Systems (TIPS) research project. In NEES 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) to evaluate current implementation of design review for seismic isolated buildings, and (2) highlight "best practices techniques" that will increase the expectation that design review is a positive experience that adds value.

The State of Practice

Research Questions

Our research is aimed at revealing how design reviews for isolated buildings conducted in practice. To understand how practicing professionals perceive the purpose, we asked participants to describe the objectives of design review. We asked a series of questions aimed at understanding how the review process has been implemented in practice with regard to scope, process, content, and level of detail. Specifically, we were interested in understanding how the details of implementation vary from project to project, the external factors that lead to variation, and how the variations affect the overall perception and satisfaction of the design review process. Understanding such variations and their outcomes is a necessary first step to making substantive recommendations.

We asked questions to determine practical experience on pivotal issues such as reviewer selection. We also asked questions to assess the impact of design review on project cost and schedule, and how the review might be conducted to minimize cost and schedule delays. The open-ended nature of the questions reflected the exploratory purpose of the study, which was to determine the range of varied opinions of experienced professionals rather than to develop generalizable data.

Besides the interview data, additional sources of information include samples of written correspondence between designers and reviewers on past projects provided by survey participants, and opinions and historical perspective from discussion with the NEES TIPS Advisory Board.

Methodology

Opinions of the design review process were gathered through telephone interviews of individuals experienced in design and/or review of base-isolated buildings. We identified potential study participants randomly and with recommendations from the Advisory Board, and requested through e-mail solicitation their voluntary participation. If the individual agreed to participate, a 30-45 minute telephone interview was conducted and transcripted by one of the authors. During the interview, we introduced our purpose, read each question, asked follow-up questions, and encouraged the participant to reply candidly and in detail.

After the interviews were complete, we used a variant of grounded theory (Glasser and Strauss 1967) to analyze the responses to individual questions. We began with an initial review of the responses during which we looked for discrete themes and key ideas. This initial review was undertaken independently by each author. Next, we conferred to discuss, define, and seek agreement on the themes and key ideas. Having done so, we conducted a thematic analysis of each interviewee's responses, coding the responses consistent with the agreed-upon themes and key ideas. Differences in individual coding decisions among the authors were discussed and resolved through dialogue.

Eighteen individuals participated in the interview process. Participants included practicing engineers, members of academia, and regulatory officials. A representative was contacted from each of the major structural design consulting firms with known recent seismic isolation design experience in the United States. Table 1 positions study participants on a matrix according to the number of isolated building projects in which they have participated as design engineer (column position) and a design reviewer (row position). For the purpose of interpretation, participants are classified as *designers* if they have designed more isolated buildings than they have reviewed and *reviewers* if the converse is true. By this classification, we interviewed 12 designers (depicted above the diagonal line in Table 1), four reviewers (depicted

Table 1. Seismic isolation experience of participants.

		Number of participants with seismic-isolation design experience					
Number of participants with seismic-isolation design review	**Projects**	**0**	**1**	**2-5**	**6-10**	**11-15**	Total
	0	2	3	1	3		9
	1			1	1	1	3
	2-5		1			1	2
	6-10					1	1
	11-15			1			1
	>15	1				1	2
	Total	3	4	3	4	4	**18**

below the diagonal line in Table 1), and two regulatory officials with no specific isolation design or review experience.

Interview Results

The interviews focused on four topics related to the design review process: (1) perceived objectives; (2) variations in the process; (3) overall perceptions; and (4) scope and content. Each topic is discussed in turn.

Objectives of Design Review

Before asking study participants to share their opinions about the design review process, we asked them to identify the process objectives. As was the case for most of the study's questions, participants were not given a list of potential objectives; instead, participants were asked to generate their own list. This approach was consistent with our overall objective of ascertaining actual practice rather than a reiteration of code or desired practice. Table 2 lists the objectives articulated by the participants and the number of participants who listed each objective. Some participants listed more than one objective.

Basic Design Review Process and Variations

Participants in our study described the typical design review process as follows. A contractor, architect, and structural engineering firm are hired for the project by the building official or client. Ideally, the design review team is organized and involved at the beginning. Next, the involved parties typically meet and define the scope of the project. After that, the design team presents the review team with preliminary documents and calculations to analyze. The review team responds with a set of inquiries or clarifications to which the design team replies. This question-response process continues until both parties are satisfied, and the design moves forward. This process more or less parallels that presented in guideline documents (e.g. ACEC 2000) as described earlier, but appears to contain more iteration, and may rely on written communication, verbal communication, or both depending on the participants' preferences and the project need.

The next phase includes the isolation device prototype testing, for which the review team is present for observation. After the prototype is approved, the review team examines the final

Table 2. Design review objectives.

Objective	No. of Participants
1. Validate design and analysis	10
2. Ensure that owner's expectations are met	8
3. Verify code compliance	7
4. Verify that enhanced performance objectives are met	3
5. Explain and interpret code	3

design and the isolation system quality control testing program. Finally, the review team gives its approval, and the plan check/permitting/construction phases ensue. Although the process described above may be considered typical, variations occur with respect to: (1) timing of the review team's involvement; (2) review team composition; (3) reviewer involvement; and (4) building type and size.

Timing of the review team's involvement. The review team may be assembled at the beginning or sometime later in the process. Study participants agreed that organizing and involving the review team from the beginning of the process positively affects the overall project outcome.

Review team composition. The number of reviewers, while typically three, may vary depending on project need. The characteristics of review team members and their experience – and the resultant outcomes – may vary from one project to another. A typical review team was said to consist of one structural engineer, one person with seismic isolation experience, and one person with seismic/geotechnical experience. According to some study participants, academic and practicing engineers take different approaches to design review that leads to different outcomes. Nearly everyone agreed that selecting reviewers who share similar philosophies with the designers can streamline the process.

The process whereby reviewers are chosen is not standardized and appears to vary by project or according to the jurisdiction. As Table 3 shows, the reviewer selection process varies in terms of how potential reviewers are identified and who makes the final selection. The selection procedure may depend on the size and scope of the project. For example, for a large historical retrofit, the owner may engage in an extensive search to obtain the best possible review team, but for a smaller new building, the owner might opt for minimally experienced reviewers or reviewers who are available at the time.

Reviewer involvement. Reviewers may choose to focus on different items and vary the extent of their involvement in the process. One participant stated that review questionnaires have varied from one to 20 pages or more. Another individual mentioned that some reviewers focus on analysis and design of the isolation components, while others focus on building performance as a whole. Finally, some reviewers perform a very high level, conceptual review while others choose to focus on details.

Table 3. Reviewer selection process.

Method	No. of Participants
The design team provides a list of potential reviewers to the owner/jurisdiction	**6**
The Structural Engineering Association of California (SEAOC) provides a list of potential reviewers to the owner/jurisdiction/engineer of record (EOR)	**6**
The building officials or owners pick reviewers without consultation	**5**
The owner/jurisdiction sends out a request for qualification or a proposal, and chooses from among the respondents	**3**
The owner/jurisdiction presents a list of potential reviewers to the design team/EOR.	**2**

Type and size of the building. Characteristics that can affect the review process are: (1) new versus existing building; (2) building size; and (3) building function. Over half of the study participants mentioned that for a new building, the review process is "cut and dry", and rarely extends beyond code requirements. For an existing building retrofit, however, achieving compliance with current codes may be a matter of judgment. The design criteria often extend well beyond the code, and likewise, the scope of review as specified by the owner or jurisdiction is likely to be more extensive. With regard to size, participants indicated that larger buildings tend to have multiple design characteristics, thereby requiring a more extensive review; the opposite applies for smaller buildings. The function of the building determines both performance objectives and the jurisdiction or agency that oversees the review process. Design review is often extended for enhanced performance objectives.

Overall Perception of Design Review

Participants' overall perceptions of the design review process were expected to reflect the range of their experiences with the process, both positive and negative. Participants were asked whether designers perceive the review process as being more positive or more negative. The designers that we interviewed were split, with five of 12 indicating that they and their peers view the process as "always" or "mostly" positive, another five view the process as "mostly" negative, and the remaining two find that perceptions depend on the circumstances. Designers' perceptions of the review process were believed to be "always" or "mostly" positive by three of the reviewers/regulators, negative by one reviewer/regulator and dependent on the circumstances by the remaining two reviewers/regulators.

Overall perceptions are a function of specific experiences. In the case of our participants, several themes emerged. As shown in Table 4, both types of participants said that the design review experience is positive when the reviewers are perceived to be qualified individuals who serve as valuable resources. Several participants noted that the review process gives engineers an opportunity to learn from others and potentially improve their designs. Likewise, the participants said that the review experience is positive when used for design verification. Finally, the participants said that the review experience is positive when engineers are open to design review, that is, when they believe that the reviewers' input is valuable and leads to a better outcome for the client.

However, a comment stated frequently by designers was that design review is negative when peer reviewers are perceived to overstep the objectives of the intended design review process. Some reviewers have been viewed as expanding the review scope and including requirements beyond the code that are not perceived to add materially to the project's quality. For instance, some reviewers seem interested in pursuing questions that are more "research-oriented" than project-focused. Both types of participants said the experience is negative when engineers are not open to design review, such as "know-it-alls" who believe that only their opinions are valid. Finally, the participants said the experience is negative when design review leads to an unjustified increase in time and money for the design firm and/or client.

Table 4. Factors contributing to a positive or negative design review experience.

Positive when …	Designer	Reviewer/ Regulator	Total
Reviewers are qualified and serve as a valuable resource	5	2	7
Used appropriately for design verification	2	2	4
Engineers open to design review	2	2	4

Negative when …	Designer	Reviewer/ Regulator	Total
Reviewers overstep the objectives	6	0	6
Engineers not open to design review	2	2	4
Increase in time and money	1	1	2

Reviewers comments helped to clarify the principal factors that influence the time and cost of design review. First, the time frame for reviewer involvement affects the process impact, such that reviewer-initiated changes requested early in the project tend to be less time-consuming and less expensive to address than changes requested later in the project. Second, if the reviewers ask for information or changes that extend beyond code compliance, both time and cost increase. A third source of increase that some may attribute to design review includes errors made by the design team that are observed by the reviewers and need to be rectified. This initiates a process of back-and-forth correction and reevaluation that inevitably takes time. Our participants did not suggest that this source of increase is problematic, but rather, demonstrates the merit of design review. Acceptance of increased expense appears to depend on the perceived legitimacy or validity of the reviewers' requests. Requests that lead to correction of critical errors or tangible improvements in design are seen as worthwhile investments of time and cost. Some of the expense of the design review may also be offset by minimizing the time or cost spent on plan checking.

One participant explained that owners and structural design firms negotiate an initial fee intended to cover the costs of the structural design and design review. Any unanticipated costs that result from the review must be covered by the structural design firm. The greater the unanticipated costs, the lower the profit margin for the designer. Such losses could reduce interest in future isolation projects, as design firms conclude that too many unknowns prevent the ability to forecast a project budget that covers costs and delivers a reasonable profit.

Participants were asked to give suggestions to minimize the time impact and separately the cost impact of design review. The suggestions for minimizing time and cost were essentially

Table 5. Suggestions for minimizing design review time and cost.

Suggestion	To minimize time	To minimize cost
Early participation of review team	7	2
Efficient scheduling and planning with clear objectives	6	3
Keep the review within the appropriate scope	2	2

the same, as seen in Table 5. Each idea appears grounded in a trusting relationship between the reviewers and the structural design team, along with early and frequent communication.

Scope and Content of Design Review

Variations in time, cost, and perception of design review are related to the scope and content of the process. Half of the study participants (n = 9) suggested that the scope of the review is a function of the code, with five participants stating that the scope is based on strict code interpretation and another four participants stating that the scope is defined to meet code compliance. Adherence to the code is only part of the story. Several participants suggested that the scope of the review might be expanded beyond the code based on the owner's objectives (n = 4) or the reviewers' objectives (n = 4). For example, enhanced performance is often expected by owners and others for base isolated systems.

As mentioned previously, designers perceive the review process to be negative when the review team expands the scope of review to include items thought to be unnecessary. For instance, reviewers may recommend performance objectives that are higher than the owner or jurisdiction demands or request additional analyses that fit the purpose of "academic learning" rather than requisite oversight. However, one individual felt that it would be unfortunate to limit the design review to code compliance only.

With regard to who defines the scope, participants indicated that more than one group typically assists in the process. For example, the scope could be primarily defined by the owner, with the assistance of the design team and/or the design review team. Table 6, which lists the participants' responses, suggests that the design reviewers and owners or jurisdictional representatives frequently assume a large role in defining the scope of review. The design team may be less likely than the reviewers to provide considerable input in defining the scope. One possible explanation for this is that the design team may appear to have a vested interest in limiting the scope of design review, since a large scope increases the likelihood of unanticipated costs that may reduce the profit to the structural design firm.

Two participants felt strongly that when the involved parties (i.e., reviewers, structural design team, owner and jurisdictional representatives) discuss and agree upon the scope at an initial stage, the resulting process is very successful. As an example of successful early participation of the review team, one firm develops a criteria document that is approved by the review team. All subsequent evaluation is measured against this document, which minimizes disagreement over the scope of review. On the flipside, a few participants shared experiences

Table 6. Participants that define the scope of the design review.

Group	No. of Participants
Design Review Team	8
Owner	8
Jurisdiction	6
Design Team or Engineer of Record	4
Mutual effort from more than one group	2

where the reviewers, when allowed by inexperienced building officials to determine the scope, expanded it to include inspection of calculations never mentioned in current codes. Unnecessary expansion of scope is seen as a continuing problem by Advisory Board members.

Closely related to the scope is the level of detail used by the reviewers to verify the design calculations. The Advisory Board feels that a high level review dominated by conceptual discussions of modeling, analysis, and thought process leading to design choices is most appropriate for isolated buildings. However, conclusive evidence points to the persistence of some problematic reviews with a greater level of detail than desired. A number of participants alluded to unnecessary detail in various parts of their survey responses. Advisory Board members described personal or secondhand accounts of reviewers trying to "take over the role of the designer" or attempting to "reproduce all the design calculations." Finally, we reviewed examples of written correspondence between the review and design teams, some of which indicated the tendency for reviewers to focus on details that have no impact on design.

Discussion and Recommendations

This study was initiated with the assumption that design review for isolated buildings is a major source of contention among design professionals, an obstacle rather than an aid to design, a process in need of significant overhaul. Perhaps the most significant impact of the study is to dispel these myths. While professionals have continuing grievances about how design review has been implemented in some projects, participants agree that design review is a worthwhile addition that adds value to the design. We received the following statements from participants when invited to comment generally, "There are clear advantages for having a design review…", "Design review does not, within itself, deter owners from opting for seismic isolation…", "The design review process has been improving with time, and is something I believe in."

To minimize the potential that the design review process degrades from succinct design verification to a cumbersome waste of resources, we recommend that isolation design reviews follow best practices described by authoritative sources and confirmed by our survey participants. We recommend that review teams be organized and involved from the inception of the design process. Owners, or jurisdictions in the case of public projects, should select the reviewers after considering input from the design team. The profession would benefit if a professional national or state organization would take the initiative to publish and maintain a list of qualified, eligible reviewers who have been selected or legitimized by their peers. This list could include individuals of various expertise and be utilized for all types of projects requiring design review.

Critically, all parties must agree on the scope of review and level of detail from the onset of the project. We recommend that the owner/jurisdiction take the lead in defining the scope of review if qualified, and that the design team and review team be given equal advisory roles when necessary. The review team should avoid assuming a dictatorial role over the design team in defining the scope. We recommend that reviewers comply with a high level conceptual review, focusing on issues that have a major impact on design decisions, unless the needs of the project justify otherwise. We recommend developing a specific process (e.g. written communication, face-to-face meetings) and schedule that can be adhered to throughout the project.

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References

American Consulting Engineers Council, (ACEC), 2000. *Guidelines for Project Peer Review*, ACEC Publication #1021/00.

American Consulting Engineers Council (ACEC) and American Society of Civil Engineers (ASCE), 1990. *Project Peer Review Guidelines*.

American Society of Civil Engineers (ASCE), 2000. *Prestandard and Commentary for the Seismic Rehabilitation of Buildings, FEMA 356*, Washington, D.C.

American Society of Civil Engineers (ASCE), 2005. *ASCE 7-05 Minimum Design Loads for Buildings and Other Structures*, Reston, VA.

Barnes, C. E., 1995. Project structural peer review in Massachusetts, *Proc. Restructuring: America and Beyond, ASCE Structures Congress*, Boston, MA.

Bell, G. R., Kan, F. W., and Wright, D. R., 1989. Project peer review: results of the structural failures II conference, *J. Perf. Constr. Fac*., ASCE **3**, 218-225.

Bell, G. R. and Roberge, C. P., 1994. Regulated structural peer review, *Civil Engineering Practice: Journal of the Boston Society of Civil Engineers Section/ASCE* **9**, 73-89.

Building Seismic Safety Council (BSSC), 2003. *NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures: FEMA 450.* Washington D.C.

Coalition of American Structural Engineers, (CASE), 1992. *CASE Document 5-1992*.

Glasser, B. G. and Strauss, A. L. 1967. *The discovery of grounded theory: Strategies for qualitative research,* Aldine, Chicago, IL.

Gross, J. G., 1986. Building structural failures – their causes and prevention, *J. Profl. Issues Engrg.*, ASCE **112**, 236-248.

International Conference of Building Officials (ICBO), 1991, *Uniform Building Code*, Whittier, CA.

Mayes, R. L., 2002. Impediments to the implementation of seismic isolation, in *Proc. ATC 17-2 Seminar on Response Modification Technologies for Performance-Based Seismic Design*, Los Angeles.

Petroski, H., 1985. *To Engineer is Human: The Role of Failure in Successful Design*, St. Martin's Press, New York.

Sharpe, R. L., 1990. Independent engineer peer review for seismic isolation projects, *Earthquake Spectra*, **6**, 309-316.

Structural Engineers Association of California (SEAOC), 1989. *Tentative General Requirements for the Design and Construction of Seismic Isolated Structures*, San Francisco, CA.

Structural Engineers Association of Northern California, (SEAONC), 1993. *Guidelines for Project Design Peer Review*.