IN NAME ONLY: PEER REVIEW OF PERFORMANCE-BASED ENGINEERING PROJECTS

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ABSTRACT:

With the ever-increasing use of performance-based structural engineering, particularly in the field of earthquake engineering, the peer review process has become almost universally relied on to ensure that performance-based seismic designs meet the intent -- rather than the letter -- of the building code. Because prescriptive requirements to ensure ductility and good behavior are being waived based on the results of performance-based analyses, and because the typical jurisdictional plan checker is unable to verify if any particular design meets the intent of the building code, public safety is increasingly being entrusted to peer review panels, which are charged with providing the necessary checks and balances in the design process but who rarely take any responsibility for the designs. Unfortunately, the peer review process is highly variable and in many incarnations has numerous flaws, leading to inconsistent levels of effort and inconsistent reliability. Through several case histories, this paper addresses the problems inherent in the peer review process and points out how each of the highlighted peer reviews derailed, failed to adhere to engineering fundamentals, and/or failed to maintain objectivity. The paper also presents a number of suggestions that, if adopted, will help reduce problems in the peer review process, including addressing the independence of the review, the scope and assignment of the peer reviewer, limitations of liability, access to computer models, and funding responsibility for the peer review.

KEY WORDS: Peer reviews, performance-based engineering, earthquake engineering

1. INTRODUCTION TO PERFORMANCE-BASED ENGINEERING AND PEER REVIEWS

Performance-based engineering, whose primary goal is to achieve better understanding and control of the parameters that govern performance, is a fairly new trend in engineering in which selected prescriptive requirements of the building code are cast aside and sophisticated analyses intended to demonstrate that a design meets the intent of the code are used in place of the explicit code provisions.

In the case of seismic engineering, many of the prescriptive requirements in the building codes were developed in reflection of the observed performance of real structures during earthquakes; other requirements are based on interpolation or extrapolation of laboratory testing, and more recently computer simulations. These prescriptive requirements are generally presumed to provide for protection of life-safety in the event of a design-level earthquake, although they are not conducive to explicit consideration of structural behavior. Nor does a code-compliant design assure achievement of any specific performance level. Performance-based engineering in a sense corrects for these deficiencies, and has evolved lock-step with improvements in available computing power and sophistication. Correctly used, performance-based engineering can facilitate behavior-explicit design of the seismic/structural system of a building in ways not previously available and can provide reasonable justification for circumvention of the prescriptive requirements of the code for either new design or modifications to an existing design.

The above notwithstanding, because performance-based analyses may result in waiver of the very prescriptive requirements normally relied upon on to ensure ductility and good behavior, and because the typical jurisdictional plan checker is unable to verify whether or not the design meets the intent of the building code, public safety is increasingly being entrusted to peer review panels, which are charged with providing the necessary checks and balances in the design process -- but which rarely take any responsibility for the designs. Peer reviews are generally considered to offer significant advantages relative to typical plan-check services; rather than a cursory review of the type that generally focuses on whether force levels were correctly calculated and whether the detailing of a proposed design generally conforms to the prescriptive requirements of the code, peer reviews are intended to be a detailed study of a given design to ensure that the design as a whole is appropriate. Unfortunately, the peer review process is highly variable and in many incarnations has numerous flaws, leading to inconsistent levels of effort and inconsistent reliability.

Now that performance-based engineering is becoming commonplace, and any engineer can claim that because a complicated computer analysis was performed that the prescriptive requirements of the building code no longer apply, peer reviews are being heavily relied upon by many owners and communities as a confirmation of seismic safety. Among other potential issues, peer reviews can be highly dependent on the materials provided by Engineer-of-Record. Depending on the specifics of the peer reviewers' stated assignment and contract, peer reviewers often have no contractual incentive to challenge a questionable design. In our experience, the ability of peer reviews to catch and correct major errors is regularly being pre-supposed when it ought not to be -- particularly given the severe restrictions on time and budget that are placed on peer reviewers, their frequent reliance on post-processed analysis summaries provided by the Engineer-of-Record in lieu of direct examination of the model and of the analysis output, and their frequent retention by the very party that has also retained the Engineer-of-Record. Endemic problems related to peer review and the associated problems with performance-based engineering (significant input assumptions, results that are highly dependent on these input assumptions, and massive amounts of relatively unintelligible computer output that is difficult or impossible to check by hand) combine to make peer-reviewed performance-based projects some of the most frightening projects currently being constructed -- and we suspect that these are among the projects most likely to have serious seismic safety problems in the future.

The case studies presented below demonstrate a number of the significant shortcomings of the peer review process.

2. PEER REVIEW CASE STUDIES

The following case studies demonstrate some of the pitfalls and problems with current peer review procedures.

2.1. Case Study #1: Peer Review of a Structure with Short/Captive Columns

Take the example of a four-story vertical addition proposed for an existing eight-story concrete perimeter moment-frame building designed in the early 1970s located in seismic Zone 4; to be permitted to add the new stories, the lateral resistance of the entire building was required by the municipal code of this major city to comply with all the structural design provisions applicable to new buildings in the current code. Since the original building was constructed in the early 1970s, such an intervention would require substantial expense and disruption if the building could not be shown to be "conforming" by performance-based analysis. Although the concrete moment frames were apparently designed to conform to the ductile requirements of the early 1970s code, the structural drawings depict classic non-ductile detailing, including column hoops at greater than d/2 spacing and inadequately confined longitudinal reinforcing splice details, with the splices located in the hinge region. In addition, a 17-inch (42-cm) thick brick-faced reinforced concrete-filled kneewall, dowelled into the slabs along their full length every 5½ inches (14 cm), reduces the clear height of the columns, thus creating numerous classic "short" or captive columns, and increases the flexural depth of the beams, thus creating strong-beam-weak-column conditions. Other structural and nonstructural compatibility issues also gave rise to potential performance problems. The building even exhibited minor x-cracking in some short columns that were most likely caused by modest ground movements of about 0.15g during an earlier earthquake.

As stated above, because this project involved a significant addition to the top of an existing building, the entire building was required by law to meet current code. To demonstrate compliance of the existing building with current code, the Engineer-of-Record for the four-story addition invoked ASCE-41, *Seismic Rehabilitation of Existing Buildings*, and performed performance-based nonlinear response history analyses -- and claimed that the analyses "proved" that the existing building with its non-ductile frame detailing already complied with all of the requirements of the current code, even considering the effect of the addition and without any strengthening whatsoever. Furthermore, on the basis of the performance-based engineering techniques used, the Engineer-of-Record claimed that the performance of the building would provide for collapse prevention during the Maximum Considered Earthquake (MCE).

Because this was a performance-based design, the municipality required that a peer review be conducted, albeit a peer review paid for by the owner and conducted under the direction of the owner's engineer. Instead of providing the analyses themselves, the owner's engineer provided only summaries of the analytical output to the peer review panel, which consisted of well-known individuals in the professional community. When the peer review panel was charged with "reporting" its findings back to the municipality, it wrote that the building was found to be totally compliant with the seismic provisions for new ductile moment resisting frames in the current building code.

Unfortunately, and unbelievably, the peer review panel had failed to recognize that the original structural drawings depicted column ties with spacing greater than d/2 and failed to recognize that the lap splices in the columns were not confined and were located within the hinge region -- perhaps because the Engineer-of-Record had provided assurances that all the detailing requirements of the code were satisfied. Worse still, the peer review panel failed to recognize that when modeling the building, the engineer had neglected to model the "nonstructural" reinforced kneewalls as well as other architectural features that could adversely affect the performance of the structure. In a later written opinion, the engineer stated that these features are "architectural elements that would be meaningless to model". Shockingly, the engineer's abject failure to model the kneewalls and other features was not recognized by the peer reviewers -- perhaps because they were focused on looking at the analysis summaries they were provided, rather than the analyses themselves. When it was pointed out by a third party that short or captive columns are a well-known cause of collapse in concrete structures and that this structure appeared to have classic short columns, instead of agreeing to model the "architectural elements", the engineer produced a "performance-based" calculation comparing the shear in a single column against the shear friction capacity of a single bay of the kneewall that showed that the 17-inch (42-cm) thick, reinforced kneewall -- dowelled in to the slab every 5-1/2 inches (14 cm) -- would fail in sliding shear before the column could fail. This postulated sliding shear "failure" is, however, a fiction given that the kneewalls are locked within the frame system and will act as struts between adjacent columns regardless of what the calculation "proved". Note that even a cursory knowledge of earthquake damage around the world would include recognition that no matter what calculations are performed, very weak materials such as poorly mortared unreinforced masonry and hollow clay tile commonly create short column failures. Despite these irrefutable logic problems with the claims made by the Engineer-of-Record, the peer reviewers accepted the calculation anyway and approved the project as compliant with today's lateral force resisting requirements for new buildings.

While the Engineer-of-Record's failure to identify short columns despite having conducted performance-based analyses could perhaps be dismissed as an act of an inexperienced engineer, the fact that this project also had two well-respected engineers who signed off on the engineer's analysis as peer reviewers and also failed to identify the short columns or any of the other clearly non-ductile details defies belief. Were it not for an interested third party who funded another independent study of the proposed project, society would have been put at risk, despite the occurrence of a peer review. Was it the contractual relationship between the peer reviewers and the owner that was to blame? Was it a limited peer review budget -- such as is typically provided to peer reviewers -- that limited the amount of independent evaluation the peer reviewers could do? The one thing we can be certain of, however, is that this was an obvious case of misuse of performance-based engineering -- and the peer review was unable to uncover it.

2.2. Case Study #2: Peer Review of a New Concrete Bearing Shear Wall Design

The authors were involved in a peer review of two new five-story concrete bearing/shear wall structures in seismic Zone 4; by time of our retention, construction of the partially completed project had been halted due to numerous questions and concerns raised by the contractor and other engineers about the design. Each tower was approximately rectangular, with post-tensioned flat slabs and a shear wall typically located at or near each exterior wall -- fairly simple structures to analyze. At the ground floor, a number of the shear walls were discontinuous and were supported by columns or transfer beams.

The well-known engineering firm based their design on a linear elastic analysis using design level earthquake forces that had been reduced by a response modification factor. Unfortunately, ductile detailing was absent from nearly every component of the lateral-force resisting system. Since the designer took the computer's recommended reinforcement design -- based solely on force -- and copied it directly to his drawings, the design was never checked against the prescriptive detailing requirements of the code. Column ties, confinement reinforcing in columns supporting discontinuous walls, collectors, diaphragm boundary reinforcing, shear wall reinforcement at coupling beams, and required boundary element reinforcing were simply omitted because the engineer never checked the output of the computer to make sure that it complied with minimum prescriptive code requirements. The engineer also failed to show standard 135° seismic hooks at the end of the transverse steel hoop reinforcement for the round columns, and approved the steel fabricator's shop drawings without catching the omission. The engineer failed to correctly estimate the weight/seismic mass of the structure and ignored deformation compatibility requirements in the code. During construction, numerous unconstructible details and conflicts were identified, and two separate engineers concluded that there appeared to be numerous problems with the design and suggested that a peer review be performed.

Three previously uninvolved engineers were retained by the owner to perform a peer review, which identified the above errors in design. When these errors were brought to the attention of the Engineer-of-Record, the engineer immediately claimed that his design was "performance-based" and therefore not subject to the prescriptive requirements of the code. The engineer admitted that when the building official asked him similar questions during the permitting process, he took his laptop into the building department and showed how the model worked -- presumably making the model "dance" in one of the primary modes -- and claimed that his was a sophisticated performance-based design. The claim of a performance-based design sufficiently impressed the building official that a building permit was granted -- despite all the obvious problems with the design.

During the peer review, the engineer refused to provide a copy of his computer model, stating that it was proprietary and that company policy prevented provide computer models for review. Since in this case the peer reviewers were adequately funded and the structure was relatively simple, it was very easy for the peer reviewers to perform a weight take-off, determine code-prescribed lateral design forces, and distribute them to the two or three shear walls in each direction via a commonly available spreadsheet program. The engineer discounted these analyses, stating that his analysis was so sophisticated, that it simply was not possible to check the design by hand. In fact, the engineer's "sophisticated performance-based" merely used an R-factor to reduce the elastic forces to design level and relied on his (essentially nonexistent) ductile detailing to provide sufficient ductility to withstand a major earthquake.

In this case, a claim of performance-based engineering was used to hoodwink a building official into accepting a clearly deficient if not dangerous design. When a peer review of the project was initiated a third of the way through construction, the engineer refused to cooperate with the peer review, refused to provide his computer model, claimed that his use of "performance-based" engineering made it impossible to check his design, and initially refused to change his design in any meaningful way. Although the peer review process worked to some degree with this project, the fact that a building official accepted a clearly deficient design due to the invocation of performance-based engineering, and the refusal of the engineer to cooperate with the peer review is cause for alarm and demonstrates the dangers involved in both performance-based engineering and peer reviews. Indeed, faced with a potentially huge liability due to gross design errors, we understand that the Engineer-of-Record's client may have gone "opinion shopping" by soliciting the assistance of yet another engineering firm to re-peer-review and attempt to back-justify a design that had already been flagged as problematic by five other experienced engineers -- at the very least, this indicates a perception on the part of the Engineer-of-Record's client that peer reviews can be used to "justify" a patently flawed design.

2.3. Case Study #3: Conflicted Peer Review Panel

The authors reviewed the work of a "peer review panel," which consisted of three leaders of the profession who were tasked with reviewing a post-earthquake damage evaluation and seismic upgrade of two existing 14-story buildings with dual systems. The costs for damage repair and any structural upgrading that might have been required by the governing authority as a result of the damage were to be borne by an insurance company.

As the proposed upgrade ballooned from $10 to $20 million to more than $140 million (at the time, more than double the cost of constructing two brand new buildings), one of the peer reviewers objected to the design philosophy that was leading to the exorbitant upgrade; rather than address his concerns, the engineer was removed from the panel.

One of the remaining reviewers argued strenuously in favor of positions advanced by the Engineer-of-Record -- including that the existing steel moment frame with high-strength bolted connections did not comply with modern code ductility requirements. When the project devolved into litigation, and that reviewer gave his deposition, he conceded that after looking at the drawings independently for the very first time, the frame was "not as nonductile" as he had been told. Unfortunately, that reviewer waited until long after the project was complete to independently review the drawings and discover that the Engineer-of-Record had misled him.

The second remaining reviewer, an academician, embarked on a massive research and testing program at his institution, ostensibly to confirm the adequacy of the upgrade design concept. The net result was that hundreds of thousands of dollars in testing fees were funneled to the reviewer and his department, the designer relied on the testing data developed by the reviewer, and the reviewer ended up essentially joining the design team rather than acting as an independent reviewer.

Needless to say, this peer review panel was an abject failure and wasn't capable of acting independently, much less providing necessary checks and balances to the design process, resulting in one of the most expensive, least efficient, and least warranted seismic upgrades ever.

2.4. Case Study #4: Conflict of Interest and Lack of Political Will

A nine-story nonductile concrete frame structure with masonry infill was significantly damaged by 0.2g ground shaking during an earthquake. This structure was located on a corner lot and had concrete walls at the bottom story property lines. Damage included cracking to the ground story longitudinal property line wall as well as to interior partitions. The damage was sufficiently severe that an upgrade of the lateral force resisting system to 75% of current code was required by a local ordinance. The engineer working for the owner designed an extremely minimal upgrade, consisting only of the addition of a single reinforced concrete wall, but attempted to justify it with significant questionable calculations. The City retained a peer reviewer who concluded that the proposed upgrade did not meet the requirements of the upgrade ordinance and that additional work was required. The owner protested and demanded a second opinion from another engineer. Instead of enforcing their ordinance uniformly and requiring that the first peer reviewer's comments be addressed, the City relented and proposed that the owner provide the names of three engineers; the City would then pick one of the three engineers to perform a second peer review. Rather than comply with this eminently fair proposal, the owner provided the name of only one engineer and insisted that this engineer be the one to perform the peer review; as it turned out, the engineer selected by the owner to perform the second peer review had a close professional relationship with the Engineer-of-Record. Given that there was a potential conflict interest between the owner's engineers, and given that there was a definite conflict of interest caused by the owner selecting and paying for the second peer review, it is not surprising that the second peer reviewer concluded that there was absolutely nothing wrong with the engineer's design. Having been trapped into agreeing to abide by the opinion of a second peer reviewer -- an engineer not of their own choosing and not beholden to protect the City's interest -- the city was unable to require modifications that would have improved the design and addressed the first reviewer's concerns.

This example demonstrates the dangers inherent in the confluence of performance-based design and peer reviews -- that unethical engineers can generate a complicated analysis to "prove" just about anything, that peer reviews can be misused or "gamed" to mislead the building official, and that peer reviews are often unable to adequately protect the public.

2.5. Case Study #5: Peer Review Performed Properly But Litigation Still Results

In this instance, at the dawn of performance-based seismic engineering nearly two decades ago, the peer review process worked surprisingly well but the end result was a disaster for all involved parties. A designer proposed using performance-based engineering to design the lateral force resisting system of a very large 18-story tunnel-formed residence hall in a high-seismic zone. The owner agreed, and a peer review panel was formed to evaluate the design proposal and provide design guidance to incorporate state-of-the-art performance-based concepts into the design. Prescriptive requirements in the code were followed unless the performance-based analyses demonstrated that the design was adequate without them and only if the peer review panel agreed. In this case, the peer review panel exercised appropriate independence and acted properly to ensure that the design met the intent and commonly understood goals of the building code.

Years after the structure was built, litigation ensued as a result of water-leakage into the building. A well-established consultant working for the owner reviewed the structural design and claimed that a small portion of the mat slab that supports the structure did not satisfy the minimum reinforcement requirements of the code. In addition, a detailed analysis by the consultant identified a few highly stressed shear wall elements. To address the purported error, the consultant recommended blocking off the surrounding streets and installing massive inclined braces around the perimeter of the building. As an alternate, the engineer recommended abandoning the ground floor altogether and filling up the story with reinforced concrete, thereby strengthening the mat. Given the outrageous repairs being suggested to address a minor prescriptive requirement that had been rendered meaningless by the use of performance-based engineering, multi-year litigation ensued, resulting in enormous costs to the owner, the designers, and the contractors. It was later shown by others that failing to conform to a prescriptive slab reinforcing requirement had no detrimental effect on the overall performance of the structure, and that any so-called critical wall elements were protected from significant damage by redistribution to nearby lightly stressed elements. In other words, the structure appeared to conform to the performance goals originally intended by the original peer review panel. The painful lesson from this example is that even if the performance-based design process and the peer review process are working perfectly, the end result may be disappointing.

3. SUGGESTIONS FOR PEER REVIEWS

Given our experiences described above, and given the importance of proper peer reviews, we have the following suggestions that should be followed when conducting a peer review.

3.1. Independence

Above all else, peer reviews must be independent in order to verify the adequacy of a design. Although peer reviewers invariably need to rely on some information from the Engineer-of-Record, the peer reviewers must include verification of the basic data -- for example, analysis summaries -- they are provided with. The peer reviewer should not assume that the engineer's work is correct; such an assumption subverts the very role of the peer reviewer, which is to determine if the work is correct.

Particular care must be exercised by the reviewer when the Engineer-of-Record has relied on highly sophisticated nonlinear analyses to justify his or her design. Nonlinear analyses -- particularly nonlinear time histories -- tend to be highly dependent on a great number of input assumptions, and when structures are subjected to loads that dwarf their elastic limits, small variations in the input assumptions can result in very large differences in the result. As described above, some peer reviewers merely rely on output or, even worse, summary tables of output from the Engineer-of-Record to determine whether the design will perform as expected; this is unacceptable, and such reliance typically negates the usefulness of the peer review. Even if the peer reviewer is not given sufficient budget to run his or her own independent nonlinear analyses, the peer reviewer should still perform independent approximate calculations to demonstrate to his or her satisfaction that the design will perform as intended.

The need to perform independent analyses is particularly acute in instances where peer-reviews are contractually limited to "topic-specific" peer reviews. Such reviews -- which are becoming increasingly commonplace -- often stem from the desire to limit peer reviews efforts (and peer review related expenses) to component-specific performance issues. The danger of this type of review is that it usually means that the peer reviewer is steered away from looking at any and all global performance issues and global analyses; yet without access to the analyses, the peer review cannot even confirm the seismic demands on the component whose behavior is being reviewed. The authors believe that this undermines the very point of a peer review.

3.2. Use of Computer Models and Other Electronic Media

Quite simply, there is nothing sacred about computer models. If the reviewer so requests, the computer models used to develop and justify the design or analysis must be shared with the reviewer. A peer reviewer should not contract to review a design whose analytical basis cannot be checked without the Engineer-of-Record as an intermediary, interpreting the output from the analysis. Having access to the Engineer-of-Record's computer model allows the reviewer to double-check seismic masses, seismic loads, structural material properties, boundary conditions, nonlinear model assumptions, and output. If errors exist in the input, it is most likely that the Engineer-of-Record does not recognize them as errors and will be unable to call the reviewer's attention to them. If the Engineer-of-Record misunderstands portions of the output, those misunderstandings may be hidden by summaries of the output prepared by the EOR for the reviewer. Ideally, to avoid the possibility that the designer uses software that the peer reviewer does not own or is not familiar with, the Engineer-of-Record and the peer reviewer should jointly select the software to be used in the design before the design is begun. If the peer reviewer is selected long after design is begun, there is some chance that the peer reviewer will be unable to review the Engineer-of-Record's computer model; in this case, the peer reviewer will likely need to develop his or her own computer model or analysis to verify the design, and additional funding may be required. Such a need should be articulated prior to executing a contract for peer review services. Merely relying on the Engineer-of-Record's representations, as was apparently done in Case

Studies #1 and #3 above, will negate the point of the peer review.

3.3. Well-Defined Scope

Given that projects that involve performance-based engineering can be subject to an increased level of second-guessing if something goes wrong, it is important that the peer reviewer's scope be well defined. The peer reviewer's retention agreement needs to spell out the goals, the scope, the assumptions, and the limitations of the peer review; failure to do so at the outset of the project can lead to misunderstanding between the various parties involved in the process, including the client, the Engineer-of-Record, the jurisdiction -- and through the jurisdiction, the public. Specifically, the scopes of some peer reviews are intended to be circumscribed by concerns about certain elements or certain aspects of behavior; these need to be clearly articulated up front. Such limitations about the concerns to be addressed by the peer reviewer does not release the peer reviewer from the need to independently check if the loading on and response of the features of concern were correctly quantified by the EOR. If the peer review is of a high profile or a higher risk project that might ultimately result in litigation (e.g. a high-rise or condominium project), a well-defined scope will be helpful in determining whether or not the peer reviewer performed according to the standard of care with respect to his or her services.

3.4. Limitation of Liability

Given that the ultimate responsibility for the design or analysis rests with the Engineer-of-Record, and given that the peer reviewer typically has little or no control as to whether or how their review comments are eventually incorporated into the design, many peer reviewers insist on a formal limitation of liability to reduce their exposure to potential future lawsuits. Such a limitation of liability, however, does not release the peer reviewer from contractual and moral responsibility to independently check the design. By the peer review process, peer reviewers become guardians of the public safety.

Given that performance-based design is often used as a substitute for complying with prescriptive requirements of the code, there generally appears to be an increased risk of litigation in the future associated with a peer review of a performance-based design, because demonstrating that a design met fairly straightforward prescriptive requirements is substantially more straightforward and less subject to equivocation than subjectively opining whether a design met the intent of the code at the time. Case Study #5 above demonstrates the hazards associated with substituting performance-based design for prescriptive requirements, and peer reviewers are correct to fear that their review will be second-guessed sometime in the future -- particularly if a design uses cutting edge technology and analyses to circumvent the prescriptive requirements of the code and the building is later damaged during an earthquake.

As long as the peer review is not intended as a substitute for plan check, as discussed in the following section, limitations of liability are not objectionable and tend to be necessary to protect the reviewer from undue liability for the reasons expressed above.

3.5. Peer Review Used as a Substitute for Plan Check

Peer reviews are of critical importance in the case where performance-based engineering is being used to circumvent prescriptive requirements of the code; special considerations are warranted in this situation. Generally, while most jurisdictions have a number of individuals who are able to assess whether or not a design meets the prescriptive requirements of the code, most jurisdictions lack the experienced personnel and resources required to evaluate whether a performance-based design meets the intent of the building code. Many jurisdictions, for example, do not have access to standard analysis software used to justify performance-based designs. Recognizing their limitations, jurisdiction will often require a peer review of a design or assessment as a substitute for plan check.

It is important to recognize that if peer review is being used a substitute for complying with prescriptive requirements, the peer reviewer is generally the first, last, and only line of defense to protect the public, and special considerations are required in this case.

In our opinion, it is essential that the peer reviewer be retained by and take direction from only the jurisdiction for whom the peer review is being conducted. Even if the cost of the peer review is ultimately borne by the owner of the building, the peer reviewer's contractual agreement must be with the jurisdiction, and payment for the peer reviewer's services must come from the jurisdiction. Contact between the owner and the peer reviewers should be limited to the same degree that contact between the owner and a typical plan checker is limited, and under no circumstances should pressure be brought to bear against the peer reviewers to ensure an outcome favorable to the owner and/or Engineer-of-Record. Failure of the jurisdiction to insist on complete independence of the reviewer from both the building owner and the Engineer-of-Record jeopardizes the safety of the public. As Case Studies #1 and #4 demonstrate, failure to obtain peer reviewers who are independent can result in peer reviewers being pressured by the owner or the Engineer-of-Record to acquiesce to a design that is patently deficient and has the potential to result in a catastrophe.

If a disagreement does arise between the peer reviewer and the Engineer-of-Record, a final decision regarding the two positions should be made by the building official; using a second peer reviewer, as was done in Case Study #4, can cause even more problems and is not recommended.

4. CONCLUSIONS

Peer reviews can be a valuable part of the design process, particularly with respect to performance-based engineering. However, peer reviews also can be inefficient and ineffective, particularly where the peer reviewers are not independent from the Engineer-of-Record. In our experience, the peer review process is highly variable and can lead to unpredictable levels of effort and inconsistent reliability. Performance-based engineering projects where the peer review is being used as substitute for formal plan check by the jurisdiction should be subject to the strictest scrutiny by the peer reviewer, because the reviewer is often the only line of defense for the public against a deficient design. Above all, it is of utmost importance that the peer reviewer be independent.

Because it often relies on sophisticated computer analyses that cannot be easily checked by hand, performance-based engineering has the greatest potential to result in abuse by the engineering profession -- either by accident or on purpose. Peer reviews are often relied upon to provide a system of checks and balances to the performance-based design process; however, peer reviews easily fall victim to conflict of interest, a lack of adequate budget and time, and failure or inability to check the design assumptions and output independently. We believe that public safety is being endangered by the failure of our profession and of society in general to recognize the ongoing and pervasive problems inherent in peer-reviewed performance-based engineering.