Seismically Vulnerable Structures and Owner's Risk in the Legal Arena: Practical Considerations for the Interim Use Period

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SUMMARY:

Following the identification of serious seismic deficiencies in a structure, an owner is faced with the challenge of determining a reasonable and prudent period of continued use of the facility pending repair, retrofit, replacement, or abandonment. That determination involves consideration of many factors, including life safety, engineering and economic feasibility, and legal exposure. Performance-based engineering provides the conceptual framework for the evaluation of the issues of expected structural performance under various seismic scenarios but it does not, and cannot, addresses issues of economic realities or acceptable risk from a legal perspective. To proactively manage legal exposure arising from serious seismic deficiencies, owners may choose between two alternatives: to vacate the facility or to continue its use. Continued use entails a potential risk to life and property. Owners may mitigate the risk of claims for personal injuries, wrongful death, and property damage by acting reasonably during an interim use period – that period between the time that the owner is on notice of the deficiency and the time that mitigation measures are completed. "Acting reasonably" can include commissioning an engineering analysis that considers likely seismic hazards, the fragility of the structure, consequences of failure, and the duration of the desired interim use period, as well as developing a mitigation program. By taking tangible steps to improve the seismic performance of a facility, the owner improves its ability to demonstrate that it acted reasonably and thereby reduce its risk of adverse judgments for personal injuries and wrongful death in the event of a damaging earthquake.

Key words: Interim Use Period; Liability; Performance-Based Engineering

1. INTRODUCTION

Despite great strides in the seismic design and construction of new structures and facilities along the west coast of the United Sates, a large inventory of buildings with significant seismic vulnerabilities remains in use. Continued use and occupancy of such buildings and facilities that do not pose a risk of imminent collapse is the societal norm. Thus, the concept of "interim use period" is not new. In reality, the interim use period is often the remaining service life of the facility. Given the low relative short-term risk of an earthquake damaging any particular building as well as significant economic considerations, the "do-nothing" approach is, from a societal perspective, not inherently unreasonable. In some circumstances, government has intervened and mandated retrofit of certain classes of facilities, including hospitals, public safety facilities, schools, unreinforced masonry buildings, and tilt-up concrete buildings. Thus, the risk associated with some of the most commonly recognized vulnerable buildings is being "managed" by regulation.

The concept of relative risk associated with driving a car is generally understood and accepted. While cars have gotten much safer over time, there remains risk of death or injury each time one travels in a car. The associated risks are accepted because the perceived benefits far outweigh the perceived risks. However, the concept of relative risk or acceptable risk in the context of buildings is neither understood nor appreciated by the general public or building owners. Rather there is a binary perception – a building is either safe or it is unsafe. Following the concept of performance-based engineering, this paper touches on the quantification and communication of relative risk from an engineering perspective and discusses how the risk associated with a seismic deficiency in a building may be managed from the legal perspective.

A building may have significant seismic vulnerabilities as a result of several conditions, such as antiquated design, architectural and structural modifications, deterioration, unrepaired damage, design flaws, or constructions defects. In some cases the vulnerability will be obvious, in some cases it will be concealed, in many cases it will be suspected, and in some cases it will come to the owner's attention through unrelated circumstances. In general, the existence of a seismic vulnerability and its significance can only be ascertained by a preliminary engineering assessment. Owners of vulnerable structures and facilities not covered by regulation may be faced with the challenge of managing the seismic risk to life, property, and business continuity posed by those facilities without clear-cut guidance regarding acceptable risk. In light of the multitude of factors to be considered, every situation is unique and there is no simple formula for prudent seismic risk management. This paper presents one possible approach to managing that risk.

2. RISK ASSESSMENT

Whether implicit or explicit, owners have seismic performance expectations for their structures and facilities. Owners of hospitals, for instance, often have explicit policies regarding providing heightened protection to patients during strong earthquakes and resuming operations immediately following major earthquakes. Other owners accept the risk of modest to moderate earthquake damage, but expect that their buildings will not collapse and will be accessible following a major earthquake (i.e., not "red tagged" in the course of a post-earthquake safety evaluation following the guidance of ATC-20 (1989) procedures).

The initial step in seismic risk management is assessing and understanding the risk of unsatisfactory performance. Even the most sophisticated owner client may not understand the expected behavior of a modern structure designed to existing codes, let-alone, that of an older structure designed to out-dated standards. Fortunately, analytical methods and performance of structures during earthquakes have improved dramatically over the past 50 years. As such, methodologies have been developed, tested, and improved upon to provide the engineer and owner the means to better assess risk in existing buildings.

While there are many acceptable methods to develop an understanding of seismic risk and prediction of seismic performance, the most commonly accepted standards are ASCE-31 (ASCE 2003) and ASCE-41 (ASCE 2006). These documents are written to provide flexibility in not only the desired level of performance, but also in the definition of the seismic hazard. These tools are continuously under development and provide excellent guidance to quantifying demand, capacity, and expected performance. While these documents were originally intended for predicting performance of older structures, they can also be used with confidence to predict performance of new structures with significant design flaws or construction defects.

As will be described in this section, evaluation of risk is a team effort between the owner and the engineer. The principle hurdles are: (i) determining the hazard and likelihood of occurrence (e.g., potential earthquake intensities and return periods); (ii) determining the level of analytical rigor (cost) of the analysis; (iii) determining an acceptable level of confidence in the results; and (iv) quantifying the consequence of failure (e.g., the three D's: death, downtime, and dollars).

One of the key questions is what level of performance (e.g., collapse prevention, immediate occupancy, or some level in between) is expected of the structure or facility in significant seismic scenarios (e.g., design basis events (10 percent probability of exceedance in a 50 year period), referred to herein as a large earthquake) and maximum considered events (2 percent probability of exceedance in a 50 year period), referred to herein as a severe earthquake). An additional area of inquiry is the likelihood of collapse, or substantial loss of capacity to withstand aftershocks.

Modern structural analysis and design software assist the engineer in developing an understanding of structural behavior and facilitate parametric studies to optimize repairs. As the level of sophistication increases, the analysis may provide better insight into the actual structural performance, potentially leading to a more efficient repair. Unfortunately, this additional cost is often perceived as prohibitive, and the benefits are often un-appreciated by owners resulting in use of analytical methods that do not provide sufficient confidence to merit a more efficient fix. Owners and/or risk managers may thus make decision to accept (or rationalize) a higher level of risk.

In those instances where a significant gap exists between the as-built seismic capacity of the structure and the foreseeable seismic demands from the considered seismic hazards, the engineer can recommend options for remediating the vulnerable condition, to bring the structure into compliance with owner's expectations. The owner can also consider modifying its performance expectations as a predicate for future abandonment or remediation of the facility. In those rare instances where owner chooses to ignore a condition manifesting a risk of imminent collapse, the engineer may have duty to bring the condition to the attention of local building officials charged with minimizing dangerous conditions in structures. Controversial methods place a statistical value on a life (Ashenfelter, 2005) to help quantify loss of life in terms of dollars; while this method may seem callous, it may help prevent loss of life by creating an economic incentive to repair or retrofit a deficient structure.

3. INTERIM USE PERIOD

Assuming first that the owner and engineer have constructive discussions concerning an unsatisfactory vulnerable condition in a particular structure and assuming second that owner has decided to mitigate the vulnerable condition, the owner may seek the engineer's advice regarding a reasonable interim use period and the relative risks involved. As the interim use period is being defined, including any limitations on areas or types of use, owner and the engineer should consider several factors, including the following four.

First, what is the temporal and spatial nature of each seismic hazard being considered? This type of information concerning distance to faults and their expected behavior is relevant to the assessment of risk during the interim use period.

Second, for each seismic hazard being considered, what is the predicted performance of the principal load paths of the structure? Which ones will perform elastically and which will perform inelastically? Which elements of each load path assembly are likely to fail and collapse? Needless to say, this involves detailed demand/capacity ratio analyses. And in the end, for each seismic scenario, the owner will need to be advised as to the practical significance of the failure of discrete elements, such as whether progressive failure is likely.

Third, for each performance scenario predicted, which parts of the facility may continue to be used as in the past, and which parts should be abandoned (or be given new patterns of use) until the remediation is completed? How many employees and visitors may be exposed to potential harm, with what frequency (daily; weekly; monthly; less frequently)? For instance, if one beam assembly in a tilt-up facility is cracked, but is unlikely to cause progressive failure, then it may be prudent for the engineer to recommend cordoning off the area immediately adjacent to the beam until repairs are completed, and allowing most of the rest of the facility to be used as in the past.

Fourth, what kind of notice should be provided to employees and visitors during the period of repair? At what point should employees be warned about hazards that could be expected to threaten life and safety during the period leading up to completion of remediation? Similarly, at what level of seismic risk should visitors be advised of specific vulnerabilities before entering a facility?

There is no single bright-line test for acceptable risk. As a starting point, prudence suggests that the greater the risk, the shorter the interim use period. Put another way, a structure facing only minor frame damage in a severe earthquake should have a longer interim use period than a structure facing general collapse.

4. RISK MANAGEMENT

For purposes of discussion, a hypothetical is offered to illustrate how the above four factors can be considered in the owner's assessment of a reasonable interim use period.

Owner operates a 20,000 square meter mixed used commercial building located in California, less than 250 meters from the Hayward fault. The building is a four-story, reinforced concrete structure, built in 1932, with a sporadically used theatre seating 600 people at the ground floor and offices on the floors above. In the course of remodelling its space on the fourth floor, a former tenant had cored through columns and the roof slab, severing primary reinforcing in both components. Owner retained an engineer specializing in structural assessments to investigate the damage to the structural components. The engineer concluded that structural capacity was seriously compromised in a significant number of the columns and portions of the structural slab. While there is no danger of collapse under gravity loads, failure of the compromised columns and slabs during a code level earthquake is likely. In the course of his/her limited investigation, the engineer notes that the structure lacks ductile detailing of the reinforcing steel and that the tall first story creates a stiffness discontinuity in the structure. Both conditions are recognized as potentially serious structural vulnerabilities. Owner agrees to engage the engineer for a more comprehensive seismic assessment of the structure as-is.

Owner's pre-existing seismic performance expectation was that the building would likely suffer significant damage but would remain sufficiently safe for retrieval of critical contents (i.e., a "Yellow Tag" scenario) following a code-level earthquake on the Hayward Fault. In the event of a severe earthquake on the Hayward fault, the owner's seismic performance expectations were that the structure would not collapse, and that any injuries would only be minor.

Based on an initial assessment, the engineer determines that the performance of the structure will likely fall short of expectations in both the design-basis and severe earthquake scenarios, both because of the tenant's rebar damage and because of the antiquated structural system. Further detailed analysis indicates that in multiple critical structural components, seismic demand will exceed capacity, leading to brittle shear failures, including some localized collapse and possible progressive collapse in the severe earthquake scenario. After receiving these initial determinations, the owner asks the engineer to identify possible repair and mitigation measures. Repair of damage to the reinforcing steel could be readily accomplished within two months without any impact to other tenants. Retrofit of the structure would require relocation of the assembly hall and tenants and would require two to three years of design and construction to complete. Owner decides to undertake both repair and retrofit, but desires to continue the use and occupancy of the building for several years until leases expire.

To make an informed decision regarding the relative risk of continued occupancy of the facility, the owner seeks input from the engineer regarding the short-term seismic risk. The engineer reports to the owner the temporal characteristics of the seismic hazard, including discussion of relative risk versus exposure time and the high level of uncertainty of when a damaging earthquake may occur, ultimately addressing short-term exposure and long-term risks. It is the engineer's opinion that the frequency of seismic activity on the Hayward fault requires either prompt remedial action or abandonment of the facility because localized collapse inside fifty years is foreseeable. Owner considers the engineer's comments and develops an appropriate interim use period, including: immediate repair of the structural elements damaged by the coring, development and implementation of seismic remediation plans, and relocation of certain tenants during the period of remediation. The engineer also works with the owner to provide formal notice to tenants and employees concerning the remediation program, and the posting of notice to theatre patrons concerning the known seismic risk.

5. LEGAL IMPLICATIONS

Whether or not owner is aware of it, owner's choices involving the interim risk period almost certainly affects owner's risk of legal exposure for adverse judgments for personal injuries and wrongful death, as well as the risk of interrupted operations resulting from excessive earthquake damage. This can be illustrated by modifying the above hypothetical involving a California mixed use facility. Assume that after owner has been informed by the engineer that the severed rebar has significantly reduced seismic capacity and before owner has taken any remedial steps, a strong earthquake takes place, causing failure of the two columns at the theater entrance, several injuries, and the death of one of the theater patrons. In California, owner could face legal claims by the injured patrons and the decedent's estate for substantial compensatory damages and punitive damages.

After learning of the seismic vulnerability of the theater, owner could have increased its chances of successfully defending against the claims by having taken corrective steps instead of doing nothing. Should the claims for compensatory and punitive damages not settle and go to trial, the judge or jury (or both) would probably consider whether owner acted reasonably under the circumstances by continuing to operate the theater before remediation was completed. Owner's chances of a favorable outcome are increased to the extent that it demonstrate that it was prudent (i.e., low risk) to operate the facility during the interim use period while it was in the process of implementing the remediation program at the time of the damaging earthquake. Conversely, owner would not have reduced its legal exposure if fails to establish that the course of action chosen was prudent from a risk perspective and that owner acted promptly to mitigate the identified vulnerabilities.

In the end, when facing claims of negligent or reckless behavior that caused personal injuries or wrongful death, an owner will have the burden of establishing that it acted reasonably under the circumstances before the seismic event, including evaluation of the relative seismic risk and pursuit of reasonable mitigation measures. Judges and juries are more likely to exonerate owners who can show that they acted prudently based on information available to them before the event.

6. CONCLUSIONS

Following the discovery of serious seismic vulnerabilities in a facility, owners are faced with the challenge of developing a risk management program Through the use of commonly accepted tools such as ASCE 31 and ASCE 41, a detailed engineering analysis can assist the owner in understanding the seismic hazard, the expected performance of the facility under various seismic scenarios, as well as the available mitigation measures. Augmenting that information with non-engineering considerations, the owner, with assistance from the engineer, can develop a rational risk management program plan, including a reasonable interim use period that is tailored to their unique circumstances. Developing and following a reasonable risk management program can help to reduce the owner's liability exposure in the event of the occurrence of a damaging earthquake during the interim use period.

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