Earthquakes: Risks, Preparation, Aftermath

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I. Introduction

Earthquakes are different than other disasters:

- They are infrequent and unpredictable. Although recent strides have been made in detection and early warning,¹ advance notice – where available – is measured in seconds, not hours or days.

- Unlike hurricanes and wildfires, there is no seasonality to earthquakes. They are a 24/7/365 risk.

- As a consequence, earthquakes afford no opportunity for an orderly, planned evacuation – or, in the worst case, for any evacuation at all. If an earthquake strikes, one’s situation over the foreseeable future will likely resemble that immediately post-temblor.

Earthquakes are similar to other disasters:

- Effects can be mitigated by good planning and risk management.

- Post-disaster challenges have much in common to those prevailing after wildfires or destructive winds.

- Knowledge evolves after each occurrence: in science; in engineering; in risk management; in governance.

- Building codes are retrospective, generally updated on a three-year cycle. To some extent, design professionals, risk managers and political leaders are always fighting the last war.

To the last point, the role of the building code suggests some fundamental questions for the business owner, property manager, counsel and others. What do I expect my building, or business, to be able to do immediately after an earthquake? What investments are needed to
make that a reality? Can it even be made a reality, given an earthquake’s effect on all the things my building or business relies upon? And given a choice, do I invest in improved seismic performance – or insure around the deficiencies?

II. Risk Management Precepts

Welcome to California, where one might expect us to be further ahead in risk management and advance planning for earthquakes than we really are. Home to the world’s most famous fault – the San Andreas, a so-called “strike-slip” fault that triggered the Loma Prieta earthquake and memorably interrupted the 1989 World Series – the state still suffers from inertia that works against effective planning. Government funding for “preventive medicine” – early warning, structural retrofits, post-disaster readiness of essential life-safety services – must compete with disasters that afflict the state without fail each year: wildfires and the debris flows they cause. Similarly, private property owners are often reluctant to allocate funds for earthquake preparedness, in favor of more immediate priorities.

California is hardly unique in being at-risk from earthquakes. Other affected regions included the remainder of the West Coast; the Rocky Mountains; an area centered on southeastern Missouri; and Charleston, SC. In fact, three of the largest earthquakes in recorded history (in terms of total energy released) were centered around New Madrid, Missouri in the early 1800’s. Hence, some risk of damage from seismic events exists over much of the nation.

A. Governing Laws

The principal laws addressing seismic safety are those which adopt model code provisions into statutes or ordinances. Before citing specific examples, it is useful to review the distinction – sometimes a source of confusion – between model codes, and the codes that are ultimately enacted into law.
In the United States, *model codes* are developed by non-governmental technical organizations (though representatives of government agencies are nearly always included as members). Larger code development organizations may publish multiple codes, covering different technical areas, with a cognizant technical committee responsible for each. For instance, the International Code Council (ICC) – one of the most prominent code development organizations active today – includes committees for its Building, Mechanical, Plumbing, Energy and other codes. The committees (along with their myriad specialty subcommittees) consist primarily of subject matter experts, most of whom serve *pro bono*.3

Code development organizations usually adopt a *consensus process model*, whose principles include, *inter alia*, interest group balance, public input, due process, and unanimity on technical issues where practicable.4 All codes, including those addressing seismic safety, cover design criteria, building and building system performance, material requirements (notably including required approvals, or *listings*, by yet other independent standards organizations), construction methods, and code administration and enforcement. Model codes are typically updated on a three-year cycle. The entire process is intended to support the ultimate objective of any building code: preservation of the life, health and safety of the public.

Material requirements are not the only aspects of codes that depend on third-party technical standards. In a very real sense, codes are compendia of detailed standards developed by other technical organizations. For steel building seismic requirements, the principal third-party standard is the *Seismic Provisions for Structural Steel Buildings*, published by the American Institute of Steel Construction (“AISC Seismic Provisions”). This standard played a pivotal role in changes to structural building codes following the 1994 Northridge earthquake, as will be discussed below.
It is here that one sense of the word “code” becomes evident: the ICC publishes the *International Building Code* (IBC), its flagship model code. In and of itself, however, the IBC is nothing but good advice. It acquires teeth only when a jurisdiction enacts it into law.

Largely because of the consensus process model, most jurisdictions adopt model codes into law with much of their original technical content intact. Deletions are rare, but states and larger municipalities usually add their own provisions to address location-specific concerns. For example, every three years California state government enacts into law a new revision to Title 24 of the California Code of Regulations. This is the multi-part *California Building Standards Code*, whose Part 2 (*California Building Code*, or CBC) covers seismic requirements, based on the IBC but with particularized requirements for medical facilities, schools, other state-owned buildings, and high-rise occupancies among others. Most, but not all, other states similarly adopt statewide standards. (Several delegate lawmaking to the county level.) In either case, the typical practice is for smaller municipalities to adopt the governing jurisdiction’s statute without technical changes. Larger cities, however, often add their own local requirements, but must include all provisions enacted at the state or county level.

At this point, the second meaning of “code” becomes clear: the IBC in modified form becomes law as the California Building Code – as well as the City of Los Angeles Building Code and others.

### B. *Role of the Building Code in Seismic Safety*

To a large extent, building codes are a repository of lessons learned from past earthquakes, though certain aspects are more forward looking. Codes generally become more conservative over time. A quantum change occurred in California, in the years following 1994’s highly destructive Northridge quake in Los Angeles. That event was the subject of intense study.
over a number of years, the results of which were reflected in revisions to the AISC Seismic Provisions, which in turn were incorporated into subsequent revisions of the CBC:

- Changes to weld materials and methods, based on failures of welds in specific types of steel connections.
- Limitations on steel strength. Interestingly, high-strength steel is not necessarily a good thing in an earthquake. It can effectively channel and concentrate seismic loads into joint welds, which may not have the same toughness as the high-strength base material – already identified as a problem as per the bullet above.
- Higher design loads for steel joints. From the Northridge experience, loads were found to be higher than expected under the dynamic conditions of an earthquake.
- Enhanced provisions to ensure weld quality.
- New performance-based requirements for steel connections.
- Assumed displacements and accelerations of building elements during an earthquake all increased significantly, generally resulting in stouter structural members and equipment supports – and added expense.

Building codes in the United States today are generally life-safety codes. That is to say, they exist to preserve life and limb both under static and upset (disaster) conditions. For upset conditions, such as earthquakes or destructive winds – this is achieved by ensuring safe egress of occupants. An earthquake can render a code-compliant building a complete economic loss – a tear-down if you will – but if the occupants all exit safely following a quake, the code, and those who designed and built to it, have done their jobs.

Thus, the key question for the owner is: what is the ultimate goal for their designers to achieve? If the goal is simply to avoid loss of life for building occupants, building to the
minimum standards of the building code will achieve this. This objective prevails for the vast majority of buildings, and it often makes economic sense: at a given level of quality, a building yields a higher return on investment if the initial investment in structure and building systems is lower. Economic losses from an earthquake can be, and often are, insured around.

If, however, the owner’s goal is to ensure that the facility being built will be able to resume its pre-disaster use shortly after a seismic event, then the owner will need to pay for a design to accomplish that. This will require engineering from all disciplines beyond code minimums, including what is likely to be a significant additional investment in structural reinforcement sufficient to withstand major seismic disasters. This might be appropriate for manufacturing facilities where the owners place a premium on continuous production, and for which available coverage limits for business interruptions may not be sufficient. It is this scenario that is most ripe for a cost-benefit analysis, accounting for the time value of money (e.g., net present value; internal rate of return), as well as statistical analysis of possible losses. The cash flows in question are initial capital costs of more-stringent-than-code construction, versus probability-weighted direct and indirect costs from the incident.

The final category for an Owner to consider might be the need for the facility to provide continuity of operation through and after a seismic event. This represents the highest level of risk avoidance and is typically the province of structures providing vital public services. Examples include power plants, water and sewage treatment facilities, hospitals, and emergency command centers. Purpose-built building standards are common for these types of facilities, to ensure continuity of service.

In recent years, an approach known as performance-based engineering has gained prominence among design professionals. It establishes objectives for a building or facility in
terms of “limit states” – the desired post-disaster conditions. As outlined above, these typically include continued operation, or immediate post-disaster occupancy. As such, performance-based engineering represents a pushback against de minimis building code requirements.

Performance-based engineering has enjoyed some uptake in the market, mostly with owners who require some degree of post-disaster functionality and with public utilities and public safety organizations. As an example, a public utility commission for a major metropolitan jurisdiction in California hired Exponent to spearhead scenario planning for the organization’s facilities and the various disasters that could affect them. Integral to the planning effort was the identification of elements for which only an investment in upgrades would suffice, as well as those whose loss could be effectively mitigated through insurance or self-insured retention.

III. Planning

Some aspects of planning differ according to whether a building is existing or planned for new construction. A prominent aspect of planning in California today is vulnerability assessment of existing buildings. Such assessments have been conducted in several major cities across the state; currently, concrete structures in Los Angeles are being examined.

Another building type has also received elevated attention in recent years: so-called soft-story construction. In essence, these are multi-story buildings with at least one floor below the uppermost that lacks shear walls to resist lateral forces. The classic example in Southern California is the mid-20th century “dingbat” apartment building, with residential floors built over an open parking garage whose structure provides vertical support only (Figure 1). Seismic failures can be catastrophic.
More recently, a number of high-rise buildings in San Francisco having certain types of moment-frame construction have been identified as at-risk in the event of a design-magnitude earthquake. A moment-frame structure is one that relies on the connections between structural members (generally installed at right angles to maximize the open area available for glazing; Figure 2) for lateral resistance. This contrasts with braced-frame construction, where lateral resistance is more dependent on cross-bracing.
Some “legacy” seismic issues remain. Unreinforced masonry (URM) construction has been unlawful in California for many decades. While mandatory retrofits have been required by law since the mid-1980’s, over 1,000 URM buildings still stand in Los Angeles alone. URM’s lack of flexibility (in many cases, with respect to more-flexible contiguous structure such as wood frame), and low capacity to resist lateral loads, make it susceptible to failure from earthquakes (Figure 3).
Vulnerability assessments are not limited to structural elements of a building. Mechanical, electrical and other systems such as public address and fire alarm must perform to-design following an earthquake. While not thought of as frequently as the building structure, these systems must have seismic capabilities of their own. In some instances, flexibility is added to mechanical systems that cross over a seismic joint in a building. A good example is fire
sprinkler piping, whose performance following an earthquake is of particular importance. Larger fire protection piping is often connected using gasketed mechanical couplings; this is not only economical but affords a good method to add flexibility through “swing” connections at the seismic joint.

The vulnerability assessment, of course, must be done in light of the owner’s performance requirements for the building, as described previously.

Once the vulnerability assessment is complete, economic risks and methods of mitigation must be considered. CGI, property/casualty and business interruption policies are all pertinent to existing buildings. For the latter two in particular, *force majeure* clauses should be closely scrutinized. For example, are there exclusions for specific construction types (e.g., soft-story) that have not been seismically upgraded? With respect to construction in-progress, how do *force majeure* provisions relate to the contractor’s duty to protect work-in-progress? It may be prudent for counsel to get help from trusted design professionals, in evaluating certain terms and conditions.

There are other risk categories to consider; these, however, lead to things a number of our clients wish they had known, or addressed more thoroughly, before disaster struck. Onward, then, to The Aftermath.

IV. **Aftermath**

“Plan in haste; repent at leisure.” This is the unfortunate scenario counsel can help its clients avoid through sound planning and risk management advice. The objective is to have a plan, and the resources to execute it, that will get a client – or perhaps even your own firm – back to the *status quo ante* as quickly as possible.
We have found our clients have been taken aback by one or more of the following after an earthquake, many of which are basic supply-and-demand issues:

- Unavailability of help from design professionals.
- Demand-driven increases in material costs.
- Unavailability of qualified general contractors; sole- or no-bid scenarios.
- Restrictions on short-term loans due to spike in the demand for cash.
- Delays in funding from insurance.
- Unavailability of goods: food, fuel, sundries. Even if an owner has 100% backup power for its property through use of a generator, the question becomes how many days’ worth of fuel do they have onsite?
- Prolonged outages of public services. The following tend to be provided to essential life-safety organizations first; commercial concerns later:
  - Power
  - Roads and street clearance
  - Water and sewer
  - Telecommunications
- Bottlenecks in inbound and outbound logistics due to impacts on roads, rail, airport and seaport facilities.
- Loss of key staff.

Of these, public utilities and logistics are among the most difficult to plan for. It is here that good business interruption insurance is perhaps most important. Once basic services are restored, advanced planning measures can make the others more manageable. Prices of fuel and
other commodities essential to business continuity can be negotiated through forward contracts; their availability post-disaster can be arranged through “front-of-queue” force majeure clauses (queues are certain to be very long post-earthquake). Availability of design and construction help can be enhanced through robust relationships with out-of-area firms, or with those having a national footprint enabling them to respond via offices located outside the affected zone.

As discussed previously, cash flow considerations are insurable; periodic review of coverage is essential. Beyond that, a firm’s cash position is an aspect of financial policy that depends on many variables, some unique to the firm or line of business. The details are beyond the scope of this paper. The relevant point is that financial readiness is a facet of disaster readiness and should be factored into the firm’s policies and procedures.

Above all, when “the big one” hits:

- Life and limb above all other considerations.
- Investigate and act on seismic vulnerabilities, whether through upgrades or risk-shifting methods.
- Plan the (disaster-related) work and work the plan.
- Place repair contracts as early as possible.
- Be prepared for overextended suppliers of goods and services and for overburdened banks and insurance carriers.
- Be as ready as possible to cope with an extended absence of public services; consider provisions to re-constitute operations outside the quake-affected area.
- Maintain a prudent cash position.
- Loop the lessons learned into the planning cycle for the next “big one” – it is a matter of when, not if.
1 In January 2019, the City of Los Angeles launched the nation’s first downloadable earthquake early-warning app, QuakeAlert, covering Los Angeles County. [https://www.latimes.com/opinion/editorials/la-ed-quake-app-la-20190105-story.html](https://www.latimes.com/opinion/editorials/la-ed-quake-app-la-20190105-story.html)

2 An interesting fact: at the current speed and direction of the two plates separated by the San Andreas fault (the Pacific and North American), San Francisco and Los Angeles will actually be co-located in 25 million years give-or-take, with the perverse result that the Giants and Dodgers will be playing in the same city.

3 As an example, the author served for over ten years on the Power Piping Committee (B31.1) of the American Society of Mechanical Engineers (ASME), which publishes a code governing the piping typically used in central station power plants. While his specialty was system design, his colleagues provided expertise in materials, fabrication, quality assurance and other specialties.

4 The ICC’s webpage provides a good summary of these principles. [https://codes.iccsafe.org/what-are-building-codes](https://codes.iccsafe.org/what-are-building-codes).

5 California Building Standards Commission: [https://www.dgs.ca.gov/BSC/Codes](https://www.dgs.ca.gov/BSC/Codes)


7 This is not necessarily true outside the U.S. Chile’s famously stringent (and enforced) building code is premised on continuity of building operation following a design earthquake – as befits a region where magnitude 9 quakes are expected.

8 See for example the 1997 California Building Standards Code, para. 1626.1: “The purpose of the earthquake provisions herein is primarily to safeguard against major structural failures and loss of life, not to limit damage or maintain function.”