RESILIENCE CRITERIA FOR SEISMIC EVALUATION OF EXISTING BUILDINGS

A 2008 SPECIAL PROJECTS INITIATIVE REPORT TO
STRUCTURAL ENGINEERS ASSOCIATION OF NORTHERN CALIFORNIA

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DAVID BONOWITZ, S.E.
605A BAKER STREET
SAN FRANCISCO, CA 94117
DBONOWITZ@ATT.NET

The SEAONC Special Projects Initiative

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ABSTRACT

This report proposes engineering criteria for estimating building downtime following earthquakes. The criteria respond to a growing need: Organizations and jurisdictions are recognizing the importance of recovery planning, but while standards exist to evaluate a building's earthquake safety and to estimate the cost of damage, little attention has been paid to the time needed to restore pre-earthquake conditions.

Clarifying previous work on this topic, the report distinguishes three milestones in the typical recovery process: reoccupancy, functional recovery, and full recovery. It proposes criteria by which to estimate the time needed, or to assess the time allowed, for functional recovery. The proposed criteria are based on the Tier 1 methodology of the seismic evaluation standard known as ASCE 31. By reviewing the many common damage patterns contemplated by ASCE 31 and assigning each one to a category of likely recovery times, new resilience-focused criteria are derived, accounting for factors such as the size of the building, its use, and the uniqueness of its contents.

INTRODUCTION

Earthquake resilience, simply put, is the ability to recover from a seismic event. Resilience is best thought of as an attribute of organizations, not buildings. Nevertheless, to the extent that organizations rely on physical facilities – structures, buildings, infrastructure – resilience has an obvious relationship to the built environment, and structural engineers have an obvious role to play in increasing the resilience of our clients and communities.

The traditional link between engineering practice and earthquake resilience is the building code's prescriptive Importance Factor. More recent codes put buildings in Occupancy Categories based in part on expected post-earthquake use. But the best engineering surrogate for resilience, not yet codified, might be the notion of "downtime."

Engineers recognize downtime as one of three main types of earthquake losses, along with casualties and direct economic costs (ATC, 2009; 2011). All three derive from physical damage, but they impact an owner or client differently. Collapse is certainly more dangerous to life than downtime, but downtime is far more common. Damage to finishes is often costly to repair, but downtime can be more disruptive. Thus, a client's attention to downtime and resilience might result in different decisions regarding building purchase, lease, occupancy, or retrofit.

The purpose of this report is to take these ideas a little further, considering earthquake resilience from the perspective of structural engineering practice – to relate resilience to structural performance, to describe it in engineering terms, and to propose practical criteria that engineers might use in everyday work.

GROWING INTEREST

More clients, from homeowners to small businesses to local governments, are thinking about recovery time as a way of measuring potential earthquake losses. Some, especially in the public sector, have indirectly raised the issue through emergency plans that set recovery targets (with or without assessment of current capacity). Others, especially businesses, have begun to address the concern through risk management. Though rare, a few organizations are working toward explicit and well-defined recovery goals. Some recent efforts from the San Francisco Bay Area:

- Community-based social service organizations need to be active in disaster response and recovery, but codes and regulations treat their facilities as typical commercial or residential buildings. The Fritz Institute's BayPrep program worked with Bay Area service providers and philanthropies to set standards for Disaster Resilient Organizations (Bonowitz, 2008).

- UC Berkeley, after working to ensure earthquake safety throughout its campus, has recognized that its mission is also at risk due to potential downtime in funded research. The University has adopted an earthquake recovery goal of 30 days (Comerio, 2006).

- On a larger scale, San Francisco Planning + Urban Research has built on the city's broad recovery goals to develop a resilience-based mitigation agenda (SPUR, 2009) and is currently developing standards to assess a building's capacity to provide post-earthquake habitability.

In some ways, this growing interest in resilience is a luxury. We can worry now about business interruption and post-earthquake habitability only because we have largely solved the problem of basic safety. That is, we have high confidence that an earthquake in the United States will not take thousands of lives. And yet, high confidence in a robust building stock comes with new expectations and new vulnerabilities. As engineers, we have done much to ensure the safety and survival of individuals. The new focus on resilience is about the survival and stability of modern institutions and communities. Recognizing this, leaders, experts, and stakeholders have come together to call for an Executive Order or Presidential Directive to promote resilience (NIBS, 2010).

LACK OF ENGINEERING STANDARDS

If efforts by a few leading organizations are encouraging, they are also each unique, because we have no engineering standards for gauging recovery time.

Our building codes have always been, and remain, focused on safety. They establish minimum requirements that implicitly allow for damage, especially to nonstructural components, but even to structural members if the earthquake is large enough. This understanding is fundamental to the development of strategies to improve resilience.

Most buildings, even if they were compliant with the codes by which they were designed and built, should not be expected to be usable after a large earthquake until substantial inspection and repairs are completed. Newer buildings can be expected to perform better, but are still designed primarily for safety. By assigning buildings to Occupancy Categories, our code presents a vague policy about post-earthquake use, requiring higher design loads for "essential" facilities (CBSC, 2010, Table 1604.5). But the provisions are prescriptive, inflexible, and largely opaque. They merely imply which facilities should be available immediately. All others, presumably, should have no expectation of being usable within any defined time.

If the building code for new construction is not resilience-based, what about the "performance-based" guidelines and standards engineers use for existing buildings? The leading engineering tools for seismic assessment of existing buildings do four things:

- They estimate the earthquake safety of a building prior to the event (ASCE 31, FEMA 154, FEMA 351).
- They provide criteria for the design of retrofits and repairs motivated by safety concerns or triggered by code provisions (IBC/CBC Chapter 34, IEBC/CEBC Appendix A, ASCE 41).

- After an earthquake, they determine if buildings are safe to occupy (ATC 20, FEMA 306, FEMA 352).
- Prior to the event, they estimate earthquake damage and loss as a percentage of replacement cost (ASTM E2557, ASTM E2026, HAZUS).

While all of these tools are suited to work with outdated structural systems, they still do not address the key resilience question: When will the building be usable again? Our leading standards, ASCE 31 (2003) and ASCE 41 (2006), consider objectives such as Immediate Occupancy and Life Safety but still do not deal explicitly with recovery time. Most businesses can afford to close for a week for clean up, but not a month or more. Social service providers and government offices are not essential in building code terms, but people rely on them to be recovered within weeks of a damaging event. And some estimate that housing reoccupancy needs to happen within days to avoid hampering a city's recovery (SPUR, 2009). We can check a building against Life Safety or Immediate Occupancy standards, but what about these cases in between?

New tools still in development (ATC, 2009; 2011) will attempt to supplement pre-earthquake safety and cost assessments with estimates of downtime. While this is moving toward a resilience standard, it is focusing only on how long it will take to complete repairs, as opposed to how soon a building's tenants can recover some measure of normalcy. What resilience-minded organizations (and their consultants) need is a way to assess whether and how the predictable damage will interfere with the organization's pre- and post-earthquake mission. The need for codes and standards that explicitly account for resilience is now recognized (NIBS, 2010).

THE SEAONC PROJECT

In 2008, the Structural Engineers Association of Northern California awarded a Special Projects Initiative grant to develop basic resilience criteria for evaluating existing buildings. The project would extend ideas initially developed for a group of San Francisco community-based non-governmental organizations that, while in the private sector, also play quasi-public roles as social service providers, with semi-essential facilities that are not well addressed by model building codes (Bonowitz, 2008). The SEAONC project would further develop these ideas for integration into standards for the full range of occupancies, including commercial and residential. By mid-2009, the framework of a proposal was developed and presented in various engineering forums (Bonowitz, 2009a; 2009b).

Additional feedback came from coordination with stakeholders and potential users. By extending the project schedule, SEAONC allowed the 2009 framework ideas to be incorporated in, and informed by, other efforts. These include:

- SPUR's Resilient City project (SPUR, 2009) and Shelter-in-Place Task Force (SPUR, 2011)
- San Francisco's Community Action Plan for Seismic Safety (ATC, 2010)
- SEAONC's Earthquake Performance Ratings Committee (SEAONC EBC, 2011)
- ASCE's current update cycle for ASCE 31 and ASCE 41.

This report concludes the project. It explains the development of proposed engineering criteria based on ASCE 31 and presents the proposed criteria, with instructions for users, in Appendix A.

DEFINING RESILIENCE

The ability to respond and recover – to bear the additional burdens of emergency conditions and to resume normal operations without lasting effects – is what this report calls earthquake resilience. While more complete multi-dimensional descriptions have been proposed (for example, by MCEER, as described by Tierney and Bruneau, 2007), this simple definition is sufficient for introducing the idea of resilience into structural engineering practice.

Two ideas are important here: First, resilience, broadly understood, is an attribute not of buildings, but of social units – households, organizations, communities. Second, resilience is measured as a combination of functional loss and recovery time. (Tierney and Bruneau, 2007)

The first idea confirms that structural engineering is necessary, but not sufficient, for resilience. For an organization with staff, clients, and data to protect, being resilient means having emergency supplies, continuity of operations plans, and thoughtful risk management, as well as limited facility damage. In general, however, a vulnerable building only makes things worse. Of course, the role of facilities varies with occupancy and with each user. Most commercial spaces are leases, and even local commerce is more and more done, or doable, online. An institution or specialized business might have stronger ties to a specific neighborhood or building type, if not to a specific address. Perhaps the most critical example of a facility-dependent occupancy is housing – quite literally a roof over your head. Whatever the occupancy, however, the important concept for structural engineers to grasp is that resilience is not about the structure; it's about the services and functions the structure supports.

The second idea combines something engineers understand well – damage – with a metric they have seldom used: time. This is the key idea behind the criteria proposed in this report. Later sections introduce the idea of a recovery objective. Like a performance objective, a recovery objective combines a desired outcome with a stipulated earthquake hazard. In this case, however, the outcome is not a measure of structural capacity loss but a measure of the time expected to restore normal services and functions.

In this report, the term resilience generally denotes a broad organizational attribute, measurable in many ways, and improvable by diverse strategies, some of which might involve structural engineering. The term recovery generally denotes the aspect of resilience measured in time after a damaging event. The two terms are closely related and are sometimes used interchangeably. While an organization's resilience and its recovery objective should consider people, operations, and physical facilities, the focus of this report is on facilities, specifically buildings, comprising structural systems, nonstructural components, and critical contents.

RECOVERY MILESTONES

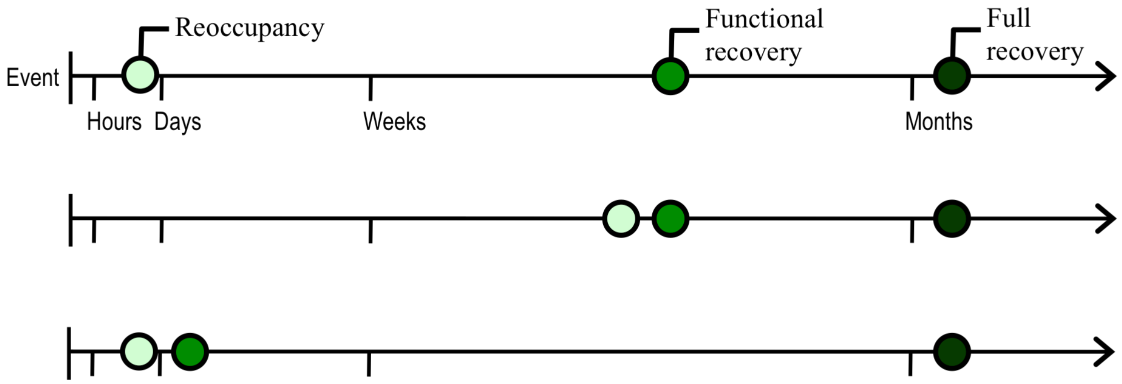
As interest in resilience grows, engineers and other stakeholders will offer various ideas about what constitutes recovery. It is useful to distinguish three important milestones:

- Reoccupancy is simply the ability to shelter-in-place within a building, or to re-enter it safely after egress or evacuation. Some damage might have occurred, and some building services might not yet be restored, but the building is safe with respect to expected aftershocks. If nothing else, tenants can at least begin cleaning up and making repairs from inside the structure. The conditions needed for reoccupancy are identical to those that would justify an INSPECTED placard or "green tag" under the ATC 20 protocol: No major structural damage or instability, no remaining falling hazards, no massive ground deformation, and no hazardous materials release (ATC, 1994). Timely reoccupancy is of primary interest to emergency managers thinking about shelter demands and to planners concerned about shuttered businesses and displaced populations (SPUR, 2009). To encourage reoccupancy, normal habitability standards are sometimes waived during an emergency period (SPUR, 2011).

- Functional recovery is a step beyond reoccupancy. It involves the restoration of building services as needed not only to provide safe shelter but also to support a significant measure of the pre-earthquake use. Cosmetic damage might remain, but most damage affecting functionality will have been repaired. In a residence, this will likely mean the restoration of utilities, security, and other requirements waived during the emergency period. In an office building it might mean the restoration of reliable power, communications, and elevators. In a theater or shop it might also require functioning restrooms and disabled access needed to properly serve the public. And in some places, like a restaurant, a service station, or a dentist's office, functional recovery probably also requires working equipment. Clearly, these "critical operations" (NIBS, 2010) are case-specific, and harder to define generically than either reoccupancy or full recovery (below). But the idea of functionality is of direct interest to most owners and tenants, and is more meaningful, in a pragmatic sense, to anyone for whom normalcy means more than mere safety. SEAONC's Earthquake Performance Ratings Committee has adopted functional recovery as a milestone for gauging downtime (SEAONC EBC, 2011).

- Full recovery is simply the state at which all damage, including cosmetic damage and non-essential building services, has been (or could have been) repaired. This is the milestone adopted by ATC 58 for its downtime measurement (ATC, 2011).

As far as building damage is concerned, reoccupancy always precedes or is simultaneous with functional recovery, and functional recovery always precedes or is simultaneous with full recovery. (If relocation is acceptable, it is possible to imagine recovery without reoccupancy, but that means the damaged building was of only marginal value to the occupancy.) While the three milestones have a clear sequential relationship, they represent different concepts of recovery, and they can occur at very different times. The following figure shows three different recovery timelines with the three milestones marked on each one.



In the top case, reoccupancy is relatively quick, but functional recovery takes several weeks, likely due to significant nonstructural or contents damage. In the middle case, reoccupancy and functional recovery are nearly simultaneous but are delayed, perhaps by some necessary structural repairs. In the bottom case, both reoccupancy and functionality are quick, and only full recovery, involving cosmetic repairs, takes longer. Clearly the three scenarios have different implications depending on how one thinks of recovery. If reoccupancy is the important milestone, the top and bottom scenarios are equivalent. If functionality is key, the top scenario is markedly worse.

In this report, recovery time is taken as the time to achieve functional recovery. As described in later sections and in Appendix A, the time to achieve reoccupancy can be estimated as a special case of the functional recovery criteria.

COMPLETING THE DEFINITION

Understanding the differences between reoccupancy, functional recovery, and full recovery resolves the biggest question in defining recovery time, but details remain to be worked out. Among the questions the engineering community should anticipate if it is to develop a consensus standard for resilience are the following:

- What is included in functional recovery? As noted above, functional recovery means different things in different occupancies and probably even means different things to different owners in the same occupancy and to different tenants in the same building. For mandatory or triggered evaluation, a standard set of requirements will need to be worked out. For now, however, most resilience assessments are likely to be voluntary, so completing a case-specific definition can be left to the project team. The criteria proposed in Appendix A therefore call for a comprehensive client interview as the first step in the evaluation process. In addition to identifying the physical assets to be evaluated, the interview should also address the broader definition of resilience by considering a client's capacity for continuity of operations more generally.

- Even with the scope of functional recovery defined, the effects of damage on downtime can vary from building to building. Some case-specific effects can be identified during evaluation and adjusted by judgment. As discussed in later sections and in Appendix A, however, the proposed criteria account for three broad conditions expected to affect recovery time significantly:
    - Building size. A damage pattern that extends throughout a building will take longer to repair in a large facility than in a small one.
    - Public use. Some damage patterns that might be tolerable to an owner-occupant (and therefore would not delay functional recovery) might be unacceptable in places that provide a public accommodation, such as mercantile and assembly occupancies.
    - Contents. Structural and nonstructural damage might be identical in two buildings, but the one whose tenants rely on unique contents or specialized equipment will take longer to recover pre-earthquake functionality.

- The notion of functional recovery presumes that restoring pre-earthquake uses is always the objective. In some cases, however, a tenant's immediate post-earthquake mission might differ from its pre-earthquake mission. This is frequently the case with government agencies that have defined roles in emergency response and with social service agencies that expect a shift or a surge in clientele during disasters. A recent study of NGOs in San Francisco, for example, found that social service agencies tend to prioritize client services over their own facility maintenance and repair (Bonowitz, 2008). A complete definition of functional recovery might need to adjust for such client-specific priorities.

- Similarly, an organization's resources and adaptability in normal times can increase or decrease when circumstances change abruptly (Tierney and Bruneau, 2007). In particular, the criteria proposed here assume that clients will seek functional recovery in the shortest possible time, living with cosmetic damage and eventually achieving full recovery with the building occupied. Where that decision would make full recovery more costly or disruptive, however, a client could as reasonably decide to relocate or postpone functional recovery in order to make all repairs at once. In these cases, a prediction of the time to functional recovery will miss low.

- Finally, while time is the rational metric for recovery, decisions tend to be made based on dollars. Indeed, one could argue that downtime is merely the first-order estimate of indirect repair costs. If monetization of recovery time becomes essential, a complete definition of functional recovery might have to include consideration of associated costs. If recovery costs the same amount in two buildings, perhaps they should be evaluated as such, even if one's down*time* is longer.

RESILIENCE NORMS: EXPECTATIONS AND OBJECTIVES

Resilience is not an entirely new concept. The necessary linkage of mitigation, response, and recovery is made clear early in California's hazard mitigation plan (OES, 2007, p. 3, Chart 2.3.2B; CalEMA, 2010, p. 4, Annex Chart 2.B). Still, the idea of assessing buildings and prioritizing projects to minimize recovery time has not yet resulted in consensus technical criteria. Where these ideas have been applied – for example, in UC Berkeley's SAFER program (Comerio, 2006) – they have been tailored to unique institutions with unique objectives.

While resilience criteria do not yet exist, normative measures of related concepts do. This report recommends melding ideas from established building codes, engineering standards, and emergency plans into technical criteria directly usable by building owners and their engineering consultants:

- From building codes comes the policy precedent that for the same earthquake, certain buildings should be designed with greater resistance than others. In the California Building Code, Table 1604.5 assigns different building uses to different Occupancy Categories (CBSC, 2010). Though the terminology of the code is inconsistent, its implication is that "essential" facilities must be able to provide more than basic safety.

- From engineering standards comes the idea of an explicit objective linking detailed measures of performance with a specified hazard. ASCE 41 standardizes this idea, for example allowing an engineer to design for "Life Safety" structural and nonstructural performance in a "10% in 50-year" event (ASCE, 2006).

- From emergency plans comes the time dimension critical to resilience. San Francisco's 2008 Emergency Response Plan, for example, envisions emergency services and restoration of normal services in three broad phases: the first week after the earthquake, the first month, and long-term reconstruction over several years (CCSF, 2008, Table 6-1).

The following table roughly compares these precedent documents by linking their broad building classifications to a generic post-earthquake timeline. For the CBC and the ASCE standards, which are not explicit about the time dimension, the time to recovery is inferred. Also, while the CBC and San Francisco's ERP cite specific building functions or occupancies, the ASCE standards refer only to generic performance levels, leaving the assignment of affected occupancies to others.

The table reveals some interesting inconsistencies and omissions. It also implies certain relationships between damage, occupancy or function, and acceptable recovery time. Some observations:

- The San Francisco ERP calls for building reoccupancy within a week of the earthquake, but the building code seeks that performance for only the most critical occupancies and functions.

- The ERP seeks restoration of social services, including health services and various government functions, within 30 days, but the available engineering standards are not especially helpful with regard to recovery times between Hours and Years. ASCE 31 provides specific assessment criteria only for Immediate Occupancy and Life Safety, and "Damage Control" in ASCE 41 is actually an undefined range that fills the gap between IO and LS.

- Industry standards were not researched for this report, but they might be useful for filling in the gaps with legal or practical precedents from the private sector. For example, are there standard lease provisions (residential or commercial) regarding an owner's responsibility to make repairs or a tenant's right to withhold rent within a certain time? Are there standard insurance provisions for loss-of-use or relocation costs that start or stop at certain times?

Time to recovery	California Building Code (2010)	ASCE 31 (2003), ASCE 41 (2006)	San Francisco ERP Earthquake Annex (2008)
Hours	Occupancy Category IV, “essential facilities”: • Emergency medical • Emergency response (fire, rescue, police, EOC) • Emergency shelters • Emergency power & backup to other OC IV facilities • Certain hazardous materials storage • Air traffic control • National defense • Water facilities to support fire suppression	Structural “Immediate Occupancy” Nonstructural “Operational” or “Immediate Occupancy”	“Critical services” (1-7 days): • Debris removal and clean-up • Emergency short-term lifeline repairs • Emergency short-term transportation repairs • Building safety inspections • Coordination with State/Federal assessments • Reoccupancy of buildings
Days			
Weeks	Occupancy Category III, “substantial hazard”: • Public assembly, 300+ people • K-12 schools, day care, 250+ people • Colleges, adult education • Medical services not in OC IV, 50+ beds • Jails and prisons • Power, water, and wastewater utilities • Certain hazardous materials storage	Structural “Damage Control” Nonstructural “Life Safety” or “Hazards Reduced”	“Ongoing social needs” (7-30 days): • Interim housing • Restoration of power, water, sewers • Restoration of social and health services • Restoration of normal city services • Economic recovery measures
Months			
Years	Occupancy Category II, default category: • Offices, housing, small public assembly, clinics, and all other buildings not in OC I, III, or IV Occupancy Category I, “low hazard”: • Agricultural buildings • Temporary buildings • Minor storage	Structural “Life Safety” Nonstructural “Life Safety” or “Hazards Reduced”	“Long term reconstruction” (several years): • Rebuilding • Restoration of transportation, housing, commercial facilities • Long term economic recovery
Never		Structural “Collapse Prevention” Nonstructural “Not Considered”	

RECOVERY OBJECTIVES

In addition to describing some regulatory gaps, the preceding table also suggests objectives for various occupancies, at least from a public policy perspective. (As noted above, industry standards regarding leasing or insurance could also make appropriate targets.)

A recovery objective states a desired maximum time to functional recovery following the occurrence of a defined earthquake. For example, for a facility providing non-emergency medical services, an objective consistent with the San Francisco ERP might be stated as "functional recovery within 30 days of an M7.2 earthquake on the Peninsula segment of the San Andreas fault." (This example uses a scenario earthquake. An engineering definition would probably use a site-specific hazard, as ASCE 31 and the building code do.)

But despite what the ERP suggests, is 30 days the right time? In concept, if actual recovery takes more time than the objective allows or desires, operations will be overly strained, and the organization's mission, presumably, will suffer. Absent legal or regulatory requirements, a rational way to determine a recovery objective might involve simple questions about an organization's typical operations. Most will involve the dollar costs of downtime, but some will no doubt address an organization's mission:

- How long can we go without revenue?
- How long until we need to lay off staff? (How long until they quit?)
- How long before we lose clients or market share?
- How long before we are in breach of our contracts?
- How long before we miss a production schedule?
- How long until our food stocks spoil?
- How long will it take to relocate our office?
- How long can we work from our homes?
- How long can we not have homes to work from?

Not surprisingly, the questions are about services and functions, not about structural performance. These are not questions that structural engineers are necessarily qualified to answer. However, if a client's answers can be translated back into foreseeable and measurable damage patterns, then we can transform the questions about critical downtime back into questions about damage and repair, such as:

- How long does it take to clear a "yellow tag"?
- How long does it take to clean up and remove debris?
- How long does it take to repair or replace broken HVAC equipment?
- How long does it take to put an elevator, security system, or computer network back in service?

The following section proposes a consistent and generic way of categorizing these questions and turning them into a tool for evaluating the recovery time of a given facility.

ENGINEERING CRITERIA FOR RESILIENCE EVALUATION

As suggested in the previous section, engineering criteria for resilience assessment need to convert foreseeable damage patterns into downtime estimates.

The criteria should focus on conditions likely to inhibit post-earthquake use. With resilience defined in terms of "time needed for functional recovery," evaluation criteria should distinguish potential damage patterns or losses based on whether they actually impact intended uses and on how long they take to clean up or temporarily repair. Notwithstanding the open questions noted above, this approach differs from seismic assessment methods that focus on safety, emergency response, or damage cost in dollars. In short, what's needed is a set of rules and procedures with which to estimate how long it will take after the earthquake to restore disrupted services and restart critical operations.

In addition, ideal criteria would be able to:

- Identify the conditions that inhibit recovery in a given facility
- Determine whether an existing facility can support a stated recovery objective
- Make useful distinctions between facilities
- Adapt to a range of conditions but be objective enough to yield repeatable findings
- Allow relatively quick and cost-effective assessment
- Mesh with existing technical standards
- Mesh with existing industry standards and regulatory precedents.

ASCE 31 AS A PLATFORM

Of our available tools, ASCE 31, *Seismic Evaluation of Existing Buildings* (ASCE 2003), comes closest to offering all these features. Its Tier 1 procedure is widely used, even if many practitioners perceive it as overly conservative. It focuses the evaluator on issue-spotting, not analysis, and it generates consistent and fairly thorough output.

A fair criticism of ASCE 31 is that while it provides a pass/fail assessment and yields a list of suspect conditions, it does not actually quantify expected damage, or repair cost, or time to recovery. For organizations interested in resilience, it would be nice to have a reliable prediction of how long it will take to recover from a given earthquake. It would be even better, given the uncertainty in earthquake size and timing, to know the probability of being able to recover in a given time period. If engineering criteria could allow an owner to look out over the next twenty years and know with, say, 80 percent confidence that she will not have to suspend operations for more than, say, three days after any event, that would be a remarkably powerful planning tool. Such a tool is in development (ATC, 2011), and its pieces exist in various forms today, but it still lacks a robust database of resilience observations from past earthquakes with which to calibrate the device. Until such a tool is available, the modified ASCE 31 approach is recommended, at least for benchmarking basic resilience.

This report therefore proposes modifying the ASCE 31 Tier 1 criteria to assess potential damage patterns in terms of recovery and resilience.

The proposed criteria are given in Appendix A. The following subsections give the rationale for the criteria and describe how they were derived by vetting ASCE 31's Tier 1 checklist items for high seismicity, and assigning each checklist item an expected downtime impact. (This report assumes familiarity with the basic contents and procedures of ASCE 31, including an understanding of how to use the Tier 1 checklists.)

RETHINKING THE ASCE 31 CHECKLISTS

ASCE 31 provides hundreds of Tier 1 checklist items in three categories: Geologic Site Hazards and Foundations, Structural, and Nonstructural. (It does not provide a particularly thorough list for owner- or tenant-supplied contents, as discussed further below.) For buildings in areas of high seismicity, each checklist item describes a design detail that, if not adequate, is said to compromise the building's capacity to perform at either the Life Safety or the Immediate Occupancy level, given the assumed shaking level.[1] Thus, one advantage of using the ASCE 31 checklists as a starting point for resilience criteria is that ASCE 31 has already thought through most of the common damage modes and potential deficiencies. The disadvantage is that it has done so with a primary emphasis on safety and on the components of an unoccupied building. The first task, then, is to reconsider each ASCE 31 checklist in terms of its relationship to service disruption and functional downtime.

Consider the ASCE 31 performance levels: Life Safety and Immediate Occupancy. At first glance, evaluation for resilience appears to be about defining a performance level somewhere between LS and IO. But it is more accurate to say that LS and IO are fundamentally different – not two points on a single performance scale, but each a fairly high point on its own performance scale, one regarding safety and one regarding recovery. From this perspective, a focus on resilience is not merely about picking an intermediate performance level. Rather, it is about filling in the different points on the recovery scale for times longer than "Immediate". Together with the recognition that functional recovery is as much or more about providing services as it is about limiting building damage, this perspective allows some useful observations:

- Every checklist item should be considered. Some items that ASCE 31 targets for their Life Safety impact (and therefore also deems important for anything "more" than safety) actually have little effect on recovery. Tall cabinets and ceiling tiles are examples; whether they tip over or fall during the earthquake is less important than whether they can be quickly cleaned up.

- Similarly, since ASCE 31 considers only one point ("Immediate") on the recovery scale, it misses the full impact of some items. Shut-off valves on hazmat piping, for example, are certainly important for Immediate Occupancy, but they are still critical even where the recovery objective would allow days or weeks for reoccupancy or functional recovery.

- Some items that ASCE 31 ignores completely can have quite large effects on recovery. Examples include specialty contents such as process equipment vital to a space's intended use. Again, from a resilience perspective, the services supported by a facility are more important than the building that houses them.

- Structurally, all that is required for reoccupancy and even for functional recovery is that the structure be "green-tagged," that is, safe to occupy. Indeed, an ATC 20 green tag or INSPECTED posting defines the structural performance that allows recovery to proceed. Therefore, a number of structural checklist items that ASCE 31 deems critical for either LS or IO performance, but which would almost never *by themselves* result in an ATC 20 red tag, need not be considered for resilience assessment. Examples include most ASCE 31 "Quick Checks," prescriptive items such as bar splice locations and tie spacing, as well as prudent (but not necessarily collapse-causing) details such as positive connections between elements.

Thus, relative to ASCE 31's Life Safety criteria, the resulting criteria would be somewhat more conservative for nonstructural components, but less conservative for structural elements. The rationale for this perhaps counterintuitive result involves several related points:

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[1] Note that Immediate Occupancy (IO) as used in ASCE 31 is not the same as the reoccupancy milestone (immediate or otherwise) described in this report. IO evaluation involves checking many nonstructural components and potential structural deficiencies that would not be expected to hinder safe reoccupancy or prevent an ATC 20 green tag. In this sense, a building that performs at the ASCE 31 IO level is almost certainly closer to the functional recovery milestone than the reoccupancy milestone.

- The difference reflects the fact that structural damage and nonstructural damage have different effects on resilience. For functional recovery, at least some of the nonstructural building systems have to work, but the structure needs only to remain standing and stable.

- Many of the structural checklist items are about details. While important, the deficiencies they suggest are unlikely to lead to severe damage in the absence of other larger problems, so they can be ignored as long as the global structural deficiencies are caught. Nonstructural deficiencies, by contrast, tend to affect individual components or systems. In theory, then, any structural checklist item required by ASCE 31 for Immediate Occupancy only would not be expected to jeopardize safety and therefore would not by itself inhibit reoccupancy.

- Finally, the difference is related to acknowledged conservatism in the ASCE 31 structural criteria, which in turn is related to engineers' traditional emphasis on safety. Some structural Tier 1 items in ASCE 31 are intentionally conservative, in order to push the evaluator toward a Tier 2 analysis. As indicators of obsolete design and construction practices, they prompt the evaluator to identify conditions that can often be ruled out or accepted later but in the worst case *might* be real deficiencies, even though the worst case is only rarely observed in actual events. By contrast, the nonstructural damage patterns contemplated by ASCE 31 are routinely observed. The resilience criteria proposed here attempt to move past that double standard. If recovery is inhibited, it shouldn't matter whether the cause was due to the structure, to nonstructural systems, or to contents.

Starting with the ASCE 31 structural and geotechnical checklists, resilience criteria can be derived by selecting those items that cover the conditions likely to lead to facility shut-down due to "red-taggable" damage. A precedent for doing this has recently been set by California's Office of Statewide Health Planning and Development, which identified a similar subset of potential deficiencies in order to set compliance schedules for mandated hospital retrofits (OSHPD, 2007).

Based largely on the OSHPD list and on ATC 20 general criteria for UNSAFE posting, this report proposes, as shown in Appendix A, that structural and geotechnical resilience criteria based on ASCE 31 need only consider the Tier 1 checklist items directly related to the following conditions:

OSHPD (2007) Deficiencies:
Material deterioration
Mass irregularity
Vertical discontinuity
Weak story
Soft story
Torsional irregularity
Low redundancy
Deflection incompatibility
Short captive column
Weak-column frames
Inadequate wall anchorage
Unbraced wood cripple walls
Precast without topping slab

ATC 20 (1994) UNSAFE Structural and Geotechnical Damage Patterns:
Partial or Total Collapse
Significant out-of-plumbness
Obvious severe damage
Massive ground movement

Additional Collapse-Prone Structure Types:
Flat slabs and flat slab frames
Unreinforced masonry bearing/shear walls
Lift slab construction
Hillside wood-frame

For the nonstructural evaluation criteria, a similar approach is recommended. However, as discussed above, potential nonstructural deficiencies have more nuanced effects on resilience. ASCE 31-03 notes (in section C3.9.3) that its Supplemental nonstructural checklist "may be used as a guide to evaluate potential disruption to building use following an earthquake." Therefore, all of the Tier 1 nonstructural checklist items are considered in deriving resilience criteria. ASCE 31-03 has three such lists for areas of high seismicity: Basic, Intermediate, and Supplemental. In the current ASCE 31 update cycle, these lists are being clarified and reorganized into two lists to suit the ASCE 31 performance levels: Life Safety and Immediate Occupancy (ASCE, 2011). Appendix A of this report takes advantage of the anticipated revisions.

Each nonstructural checklist item suggests a damage pattern or failure mode. To derive resilience criteria, each of these anticipated damage patterns is assigned a likely repair scope with a typical duration, from substantial clean-up (hours) to disruptive repair (months). This process effectively associates each checklist item with one or more recovery objectives, as illustrated in the next section.

This report proposes supplementing the ASCE 31 nonstructural checklists with additional items regarding contents, as shown in the next section and in Appendix A.

MAPPING DEFICIENCIES TO RECOVERY TIMES

Recovery time is not a familiar metric to structural engineers, nor is it supported by a robust record of observations or research. Therefore, for an initial set of resilience criteria, this report proposes a simple set of time categories: Hours (H), Days (D), Weeks (W), Months (M).

The H-D-W-M values are intentionally fuzzy and overlapped, so as not to give the false impression of undue precision. They also have the advantage of being intuitive and vernacular, so as to facilitate their use with clients, without setting up a screen of jargon. Conveniently, they represent progressively longer units in a way that captures the progressively wider errors and uncertainties associated with predictions of longer recovery times. And importantly, they are objective terms, as opposed to judgmental labels such as “fast,” “minimum,” or “acceptable.”

In concept, a checklist item (and the potential deficiency it anticipates) is critical for a given recovery objective if the necessary repair would take more time than the objective allows. For example, if a checklist item about ceilings suggests a damage pattern that would prevent recovery for Days, then the evaluation should consider that checklist item if the objective desires recovery in Hours or Days. If the recovery objective involves Weeks or Months, this checklist item may be ignored.

As discussed above, the structural and geotechnical criteria are based on ASCE 31 checklist items only for severe deficiencies. For each of these, the anticipated damage would be severe enough that structural repair (likely including investigations, design, and construction) cannot be fairly assumed to take less than a month. Therefore, the proposed criteria consider every geotechnical and structural checklist item critical for any recovery objective, from Hours to Months.

The nonstructural and contents checklist items, however, are more variable in scope and effect. While the same questions apply – What would the repair involve and how long would that normally take? – the answers range considerably. The following table lists various scopes of nonstructural component repair and proposes a categorization of them by the recovery time categories. The longest recovery time listed is essentially how long the repair or remedy is assumed to take.

Recovery effort suggested by various damage patterns	Recovery times for which the issues are likely to be critical
Repair of cosmetic damage, especially in unoccupied areas Loss of expendable items Light clean-up or non-hazardous debris removal	Moot (ignore)
Substantial clean-up, not requiring outside crews Blocked egress due to contents damage	Hours
Extensive clean-up or non-hazardous debris removal Removal or repair of remaining falling hazard Clean-up of hazardous materials release	Hours, Days
Replacement or repair by specialty contractors	Hours, Days, Weeks
Disruptive repair requiring building or space to be vacated Repair of nonstructural damage from fire or explosion	Hours, Days, Weeks, Months

Of course the categorization in the preceding table is approximate and judgmental. Aside from its basis in judgment, this categorization also assumes incorrectly (if necessarily) that a given damage pattern always takes roughly the same time to repair, regardless of other conditions. To account for this, the proposed criteria adjust the initial categorization in three ways:

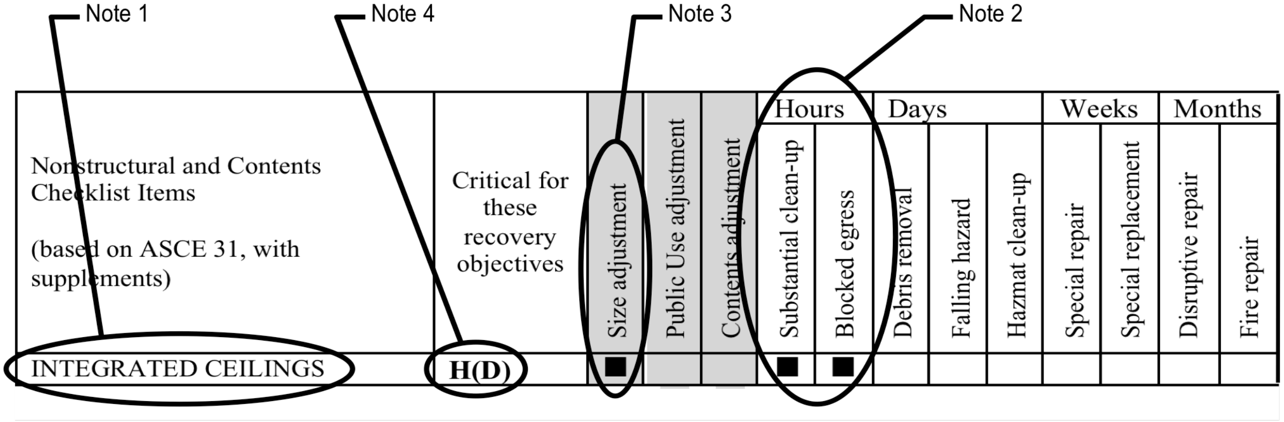
- Size. This adjustment applies where the recovery time associated with a large building would be proportionately larger than the same damage pattern in a small building. Generally this applies to distributed nonstructural systems, but it can also apply to contents. A five-story building, for example, has more window wall and more water piping than a one-story building, but it does not have substantially more parapet length or more boilers. (The adjustment is necessarily approximate. Further distinctions between, say, 5-story 20-story, and 40-story buildings are left to the evaluator’s judgment.)

- Public use. This adjustment applies where the degree of repair needed to restore functionality in a public space would be much greater than that needed to serve tenants willing to function temporarily with some unrepaired damage. Generally this relates to issues of habitability and legal compliance. For example, the tenants of a small office within a building might be willing to recover their business operations without air conditioning or elevators. Another space in the same building that needs to accommodate the public or a large and diverse employee group might not be able to make such sacrifices, so its functional recovery could take longer.

- Contents. This adjustment applies where the functionality of a space relies disproportionately on specialized equipment or performance requirements. Examples of such “process equipment” might include items found in labs, machine shops, medical offices, clean rooms, hotel kitchens, or other light industrial occupancies.

If one of these adjustments applies, the critical recovery objective for which the checklist item must be considered is shifted up one level, for example from Days to Weeks. If two adjustments apply, the critical objective is shifted up two levels, for example from Days to Months. Again, the adjustment is approximate and somewhat arbitrary, and therefore subject to revision as data becomes available.

This process was applied to each ASCE 31 nonstructural checklist item, as well as the supplemental contents items. The long table at the end of this section shows the results. The following graphic and notes illustrate the process for a sample ASCE 31 item: INTEGRATED CEILINGS.



Nonstructural and Contents Checklist Items (based on ASCE 31, with supplements)	Critical for these recovery objectives	Size adjustment	Public Use adjustment	Contents adjustment	Hours		Days			Weeks		Months	
					Substantial clean-up	Blocked egress	Debris removal	Falling hazard	Hazmat clean-up	Special repair	Special replacement	Disruptive repair	Fire repair
INTEGRATED CEILINGS	**H(D)**	■			■	■							

1. Each nonstructural and contents checklist item is considered. The ASCE 31 Evaluation Statement labeled INTEGRATED CEILINGS calls for certain suspended ceilings (typically T-bar grid ceilings) to be laterally restrained with diagonal wires. The damage pattern associated with ceilings that are *not* adequately braced in this way involves lightweight panels (generally 2 ft by 2 ft or 2 ft by 4 ft) falling out of the grid, and probably some distortion of the grid members as well.

2. The downtime associated with the anticipated damage pattern involves only the time needed to clean up the fallen ceiling panels, which requires no special expertise, and/or the time needed to ensure that egress paths are not blocked. Once these measures are taken, functional recovery is achieved. Each of these recovery measures is in the Hours category. If the ceiling grid is damaged, its repair will certainly take longer than a few hours; in many cases, an owner will opt to upgrade the ceiling with bracing in order to prevent repeat damage. These extra measures, however, do not impede functional recovery, which is feasible without the ceiling tiles in place.

3. Of the three adjustments (shown in the shaded columns), only the Size adjustment is expected to apply to typical ceiling installations. That is, if panelized or integrated ceilings are used in one part of a building, they are likely to be used in other parts as well. If the same damage were widespread throughout a large building, recovery would take substantially longer than it would in a small building, so the adjustment applies. The Public Use adjustment is not expected to apply because the absence of a fully repaired ceiling generally does not inhibit use of a space by non-tenants. The Contents adjustment is not expected to apply because panelized ceilings are widely available and not crucial to the functions being recovered. In all cases, however, the evaluator may, and should, review the assumed application of these or other adjustments to the basic downtime category.

4. **H(D)** indicates the final result of the process. In this case, the basic downtime estimate is Hours (see Note 2), so the critical recovery objective for which this item must be checked is also Hours. Since one of the three adjustments applies (Note 3), the next recovery time category, Days, is also indicated, but in parentheses. This notation can be found adjacent to the INTEGRATED CEILINGS checklist item in Appendix A.

This mapping of checklist items to critical recovery objectives is based on the functional recovery milestone (see the previous discussion in this report). Criteria based on the reoccupancy or full recovery milestones could be derived through a similar process. For full recovery, such an exercise would make longer recovery times critical for many items (for example, **HDW** or **HDWM** instead of **HD**). For reoccupancy, the critical recovery times would be shorter; in fact, many would become moot, as the anticipated damage patterns would not be expected to delay reoccupancy at all. The proposed criteria approximate this by using green shading to indicate a reduced scope of work when only the reoccupancy milestone is of interest. In the table below, as in Appendix A, green shading indicates that the checklist item is required for evaluating relative to the reoccupancy milestone. In the illustration above, the row for INTEGRATED CEILINGS is not shaded green, so an evaluation for reoccupancy would not have to consider that checklist item at all. This makes sense because the loss of ceiling tiles, even if they need to be cleaned up, would not inhibit a green tag.

Conceivably, criteria for full recovery could be approximated from the functional recovery criteria as well, but this report does not make a recommendation in that regard. Since the structural criteria proposed for functional recovery are only a subset of the ASCE 31 structural checklist, even a building that fully complies with them might still sustain damage that would require minor structural repair.

Additional notes regarding the assignment of critical recovery times to ASCE 31 checklist items:

- Condition assessment items (such as those regarding material deterioration) are assigned to the most conservative recovery times associated with the element or component type they address. For example, the item for DETERIORATION of masonry veneer is assigned to the worst case recovery time of any Evaluation Statement about the design or construction of masonry veneer.

- The proposed criteria are intended to be suitable for evaluating individual spaces within a building as well as whole buildings. When evaluating an individual space for the functional recovery milestone, the evaluator may apply the green-shaded reoccupancy criteria to elements and components whose damage would only affect parts of the building outside the area of interest, and should apply the full set of proposed criteria to everything else.

- One shortcoming of the proposed criteria is that they do not distinguish between a building with one non-compliant condition and a building with 10 or 50 non-compliant conditions. Both buildings would simply be found non-compliant with the objective, and it would be left to the evaluator to apply further judgments regarding significance. This is an important criticism, but the same criticism can be leveled against the use of ASCE 31 safety evaluations. For now, the problem remains with both ASCE 31 and the ASCE 31-based resilience criteria proposed here.

- The proposed criteria include no adjustment for buildings with asbestos-containing materials (ACM). The presence of ACM can significantly delay and increase the cost of retrofits and repairs. The effects are sometimes significant enough to change an owner's decisions about whether and how to proceed. The proposed criteria do not address ACM directly, but the procedure recommended in Appendix A does suggest a review of available ACM data during an initial interview stage.

- The proposed criteria do not account for the possibility that municipal utility services might not be restored by the time building repairs are made and functions are ready to resume. The proposed criteria assume that the building will have power, water, and other services available. If this is cannot be fairly assumed, the recovery times predicted for certain components would have to be combined (perhaps in parallel, perhaps in series) with utility recovery schedules.

- The proposed criteria assume that construction materials, replacement components, and skilled labor will be available after the earthquake. ATC 58 (ATC, 2011) makes the same assumption.

The following table shows the basis for the nonstructural and contents criteria in Appendix A.

Nonstructural and Contents Checklist Items (based on ASCE 31, with supplements)	Critical for these recovery objectives				Hours		Days			Weeks		Months	
		Size adjustment	Public Use adjustment	Contents adjustment	Substantial clean-up	Blocked egress	Debris removal	Falling hazard	Hazmat clean-up	Special repair	Special replacement	Disruptive repair	Fire repair
Life Safety Systems													
EMERGENCY LIGHTING	**HDW(M)**		■			■				■			
EMERGENCY POWER	**HDW(M)**		■			■				■			
FIRE SUPPRESSION PIPING	**HDWM**		■		■		■					■	
FLEXIBLE COUPLINGS	**HDWM**		■		■		■					■	
STAIR AND SMOKE DUCTS	**HDW(M)**		■							■			
Hazardous Materials													
TOXIC SUBSTANCES	**HDWM**		■	■	■				■			■	
GAS CYLINDERS	**HDWM**		■						■			■	■
SHUT-OFF VALVES	**HDWM**		■						■			■	■
HAZMAT EQUIPMENT	**HDW(M)**		■	■					■		■		
FLEXIBLE COUPLINGS	**HDWM**		■						■		■		■
Partitions													
UNREINFORCED MASONRY	**HD(W)**	■				■	■	■					
URM WALLS (at stairs)	**HD(W)**	■				■	■	■					
DRIFT	**HD(W)**	■				■	■	■					
SUPPORT	**HD(W)**	■				■	■	■					
STRUCTURAL SEPARATIONS	**H(D)**				■	■							
TOPS	**HD(W)**	■			■	■	■						
Ceilings													
INTEGRATED CEILINGS	**H(D)**	■			■	■							
LATH AND PLASTER	**HD(W)**	■				■	■	■					
LAY-IN TILES	**H(D)**	■			■								
EDGES	**(H)**	■											
SEISMIC JOINT	**(H)**	■											
Light Fixtures													
INDEPENDENT SUPPORT	**HDW(M)**	■					■	■		■			
LENS COVERS	**H(D)**	■			■								
PENDANT SUPPORTS	**HDW(M)**	■			■					■			
OTHER LIGHT FIXTURES	**HDW(M)**	■			■					■			
Cladding and Glazing													
CLADDING ANCHORS	**HD(W)**	■				■	■	■					
CLADDING ISOLATION	**HD(W)**	■				■	■	■					
MULTI-STORY PANELS	**HD(W)**	■				■	■	■					
PANEL CONNECTIONS	**HD(W)**	■				■	■	■					
BEARING CONNECTIONS	**HD(W)**	■				■	■	■					
INSERTS	**HD(W)**	■				■	■	■					
OVERHEAD GLAZING	**HD(W)**	■				■	■	■					
GLAZING RESTRAINT	**HD(W)**	■				■	■	■					
GLAZING FUNCTIONALITY	**HD(W)**	■					■	■					

Nonstructural and Contents Checklist Items (based on ASCE 31, with supplements)	Critical for these recovery objectives	Size adjustment	Public Use adjustment	Contents adjustment	Hours		Days			Weeks		Months	
					Substantial clean-up	Blocked egress	Debris removal	Falling hazard	Hazmat clean-up	Special repair	Special replacement	Disruptive repair	Fire repair
Masonry Veneer													
SHELF ANGLES	**HD(W)**	■				■	■	■					
WEAKENED PLANES	**HD(W)**	■				■	■	■					
TIES	**HD(W)**	■				■	■	■					
STUD TRACKS (Metal Stud)	**HD(W)**	■				■	■	■					
OPENINGS (Metal Stud)	**HD(W)**	■				■	■	■					
ANCHORAGE (Masonry)	**HD(W)**	■				■	■	■					
URM BACK-UP (Masonry)	**HD(W)**	■				■	■	■					
Parapets, etc.													
URM PARAPETS	**HD**					■	■	■					
CANOPIES	**HD**					■	■	■					
CONCRETE PARAPETS	**HD**					■	■	■					
APPENDAGES	**HD**					■	■	■					
TILE ROOFING	**HD**				■	■		■					
ADJACENT APPURTENANCES	**HD**					■		■					
ADJACENT BUILDINGS	**HD**					■		■					
Masonry Chimneys													
URM CHIMNEYS	**HD**						■	■					
ANCHORAGE	**HD**						■	■					
Stairs													
STAIR DETAILS	**HDW(M)**		■			■				■			
Contents and Furnishings													
TALL NARROW CONTENTS	**H(DW)**	■		■	■	■							
OPEN SHELVING	**H(DW)**	■		■	■	■							
PALLET RACKS	**HD(WM)**	■		■	■	■		■					
ACCESS FLOORS	**HDW(M)**	■		■	■					■			
EQUIPM’T ON ACCESS FLOORS	**HDW(M)**	■		■	■					■			
FILE CABINETS	**(HD)**	■		■									
CABINET DOORS, DRAWERS	**(HD)**	■		■									
OWNER-FURNISHED EQUIPM’T	**H(DW)**	■		■	■								
COMMUNICATIONS EQUIPM’T	**HDWM**			■							■	■	
PROCESS EQUIPMENT	**HDWM**	■		■							■	■	
PROCESS POWER	**HDWM**	■		■							■	■	
Mechanical and Electrical													
GAS-FIRED WATER HEATERS	**H**				■								
SOLAR PANELS	**(H)**			■									
TANKS	**HDW(M)**			■						■			
ATTACHED EQUIPMENT	**HDW(M)**	■		■	■	■		■			■		
VIBRATION ISOLATORS	**HDW(M)**			■						■	■		
ELECTRICAL EQUIPMENT	**HDW(M)**			■						■			
DOORS (Mechanical)	**HDW(M)**		■			■				■			
HEAVY EQUIPMENT	**H(DW)**	■		■	■								

Nonstructural and Contents Checklist Items (based on ASCE 31, with supplements)	Critical for these recovery objectives				Hours		Days			Weeks		Months	
		Size adjustment	Public Use adjustment	Contents adjustment	Substantial clean-up	Blocked egress	Debris removal	Falling hazard	Hazmat clean-up	Special repair	Special replacement	Disruptive repair	Fire repair
Piping													
SPRINKLER HEADS	**HDW(M)**	■		■	■		■			■			
FLEXIBLE COUPLINGS	**HDW(M)**	■			■		■			■			
PENETRATIONS	**HDW(M)**			■	■		■			■			
FLUID PIPING	**HDW(M)**	■			■		■			■			
C-CLAMPS	**HD(W)**	■			■		■						
Ducts													
DUCT BRACING	**HDW(M)**	■								■			
DUCT SUPPORT	**HDW(M)**	■								■			
Elevators for critical occupancies	**HDW(M)**		■							■			

OPEN ISSUES

Finally, this section acknowledges a number of implementation issues outside the scope of this report or the proposed criteria:

- Open issues discussed previously in this report:
    - The need for a broad assessment methodology for earthquake resilience, of which these facility-related criteria would be a part.
    - The need for criteria to distinguish a building with one deficiency from a building with many deficiencies (a current problem with ASCE 31 in general).
    - The need for similar criteria based on the full recovery milestone. The ATC-58 project is expected to address this issue, though with procedures and criteria more thorough and complex than those proposed here (ATC, 2011).
    - The need to account for asbestos-containing materials.
    - The need to account for non-recovered municipal utility services.
    - The need to account for the possibility of unavailable replacement equipment, construction materials, or skilled labor.

- Accounting for externalities. Externalities are conditions outside a client's control that can affect her recovery time and resilience overall. Examples related to the facilities component of resilience might include:
    - Failure or long recovery time of municipal utility services.
    - Risks from adjacent properties, such as falling hazards that restrict access or otherwise require the building of interest to remain vacated.
    - Availability of supplies and skilled labor to implement repairs.
    - Unclear or unavailable decision-making authority. Recovery in a leased facility might depend on decisions made by the landlord or other tenants. The local jurisdiction might also need to make decisions about safety, traffic, etc.

- Use of resilience evaluation results to guide retrofit design. The findings of a resilience evaluation may be used to guide a voluntary retrofit design, but they should not necessarily be used as retrofit design criteria, nor should the design objective for the retrofit always be the same as the recovery objective. This is because the purpose of a basic resilience assessment, for which the proposed criteria were developed, is simply to identify potential mission-jeopardizing conditions. In deciding whether to retrofit, other factors can and should be considered:

  - Code compliance. If the retrofit is mandated or triggered, as opposed to strictly voluntary, then regulations other than the proposed criteria will apply. Similarly, the intended work can sometimes trigger additional work, such as hazardous material abatement or disabled access improvements, which are governed by separate regulations.
  - Effective planning. While earthquake resilience is clearly a laudable goal, it should be balanced with an organization's other goals. It is usually most effective to make resilience improvements within the context of a larger and more comprehensive facility improvement plan. For similar reasons, a retrofit should not be scoped simply to achieve a credential or a badge of compliance with these novel and still untested criteria.
  - Even when the decision is made to retrofit, resilience need not be the only design objective. Rather, building improvements should usually be scoped so as to have the most effective impact on performance overall, considering safety, economy, durability, and life-cycle costs.

- Trial applications and consensus development. The resilience criteria proposed in this report are new and untested. As modifications to an existing engineering standard, they warrant peer review and testing before being adopted for widespread use.

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APPENDIX A: PROPOSED CRITERIA FOR RESILIENCE ASSESSMENT

This Appendix proposes the modifications to ASCE 31 that are needed to implement the ideas presented in the body of this report. It is assumed that the individual responsible for the resilience assessment is familiar with the ASCE 31 standard. Though not necessary in all cases, it is expected that the evaluator will be a qualified engineer.

Specific notes about the derivation of the criteria are given in the body of this report. General notes on the adaptation of ASCE 31:

- The criteria are based on ASCE 31 Tier 1 Evaluation Statements (also known as the Tier 1 checklists) for areas of high seismicity. As with ASCE 31's Tier 1 safety criteria, the proposed resilience criteria are suitable for cost-effective preliminary assessment. They are intended only to identify deficiencies likely to jeopardize an owner's recovery objective, which itself is based on self-identified mission-critical functions and services. Tier 2 and Tier 3 procedures remain the same. That is, a potential deficiency identified in Tier 1 can be ruled out by Tier 2 or Tier 3 analysis.

- There is room for judgment. The Tier 1 checklists contemplate common conditions in typical building structures. Where actual conditions are atypical, the applicability of a particular statement and the significance of the nominal response to it should be explained by the evaluator. The proposed criteria do not apply directly to highly specialized or complex industrial, manufacturing, or similar special use facilities.

- The proposed criteria are based on ASCE 31-03 but reflect reorganization and slight rewording of the nonstructural items expected for the next edition (ASCE, 2011). Changes and additions to this wording are shown in ~~strikeout~~ underline format. The added items reflect the understanding (from FEMA E-74, 2011, and elsewhere) that contents, while often ignored by engineering codes and standards, can profoundly affect earthquake resilience.

- A building that satisfies these criteria does not necessarily satisfy the Life Safety or Immediate Occupancy criteria of ASCE 31. This is because the checklists included here include only subsets of ASCE 31's Foundations and Structural checklists. (The Geologic Site Hazards and Nonstructural checklists are included in their entirety, but with emphasis on functional recovery, not safety or damage control.)

- Checklist selection and eligibility for benchmarking is explained at the top of each checklist section.

INTENDED USE

Because the proposed criteria are not strictly about safety or specifically for certain occupancies, they are unlikely to be invoked through the building code or through mandating legislation. Rather, they are most likely to be used voluntarily. As such, like ASCE 31 and its predecessors, the proposed criteria can be used in various ways to suit various purposes.

- They can be used as a comprehensive tool to gauge an existing facility. In this case, a complete evaluation is done, and the results are used to better understand the expected recovery time.

- Second, they can be used to check a building against a stated recovery objective and, commonly, to set the scope for mitigation. In this case, only those checklist items critical to the stated objective need to be considered. (This is similar to using ASCE 31 for a Life Safety evaluation and ignoring the issues required only for Immediate Occupancy evaluation.)

- Third, they can be used for triage efforts to make quick assessments or distinctions between buildings with respect to one or more pre-selected issues. In this case, a focused evaluation stops as soon as it finds enough deficiencies to bin the facility.

The proposed criteria omit certain provisions that ASCE 31 requires for Life Safety evaluation. Therefore, compliance with these resilience criteria does not necessarily assure reliable Life Safety as defined by ASCE 31. These criteria should not be used if strict compliance with ASCE 31 is sought. Further, earthquake damage to components not addressed by these criteria might still require repair in order to recover safe operations.

EVALUATION REQUIREMENTS AND INSTRUCTIONS

In general, the requirements and instructions in ASCE 31 for its Tier 1 procedure apply to these proposed resilience criteria. ASCE 31 Tier 2 or Tier 3 procedures may be used to clear any deficiencies identified in Tier 1.

In addition, the nature of this evaluation calls for additional investigation at the start of the process. Evaluation of an organization's facilities should be part of a broader program of resilience planning. While the findings can be used to scope voluntary risk reduction, they are intended primarily to supplement other self-assessments regarding an organization's emergency and continuity of operations planning. The following additional steps are recommended:

1. Client interview. As with all performance-based procedures, it is important for non-expert clients to understand the intent and limits of a resilience evaluation, how it differs from a safety evaluation or a loss estimate, and how it differs from a compliance-based evaluation (such as a building code review). The interview is also essential for understanding the client's desires, expectations, and capacity with respect to the facility-related recovery milestones: reoccupancy, functional recovery, and full recovery. Often the client's understanding of recovery will be less complete than her understanding of safety or financial loss. Just as often, the engineer's understanding of a client's operations will be less complete than his understanding of the structure. The interview is intended to reach a mutual understanding of the following scope decisions. In addition, a preliminary interview, together with the document review required by ASCE 31, is an opportunity to confirm or rule out the presence of asbestos-containing materials and to assess their potential impact on the evaluation scope and findings.

2. Recovery milestone. As discussed in the body of the report, there are many definitions of resilience, so measuring recovery on a time scale requires that one be chosen. The proposed criteria are developed primarily for the functional recovery milestone, at which occupancy-specific building services are restored but secondary and aesthetic repairs remain incomplete. The proposed criteria may be used to gauge reoccupancy as well, by using only the green-shaded checklist items. The proposed criteria are not recommended for evaluating the full recovery milestone.

3. Scope of evaluation. The proposed criteria may be used for whole buildings or for spaces within buildings. Where only certain spaces are considered (as for leases within larger buildings), the initial stage should identify how the functionality of the space is related to the functionality of other spaces and of the building as a whole. Nonstructural components and contents outside the space in question need only be evaluated with respect to the reoccupancy milestone. An understanding of the scope of evaluation also influences the application of the adjustments for size and public use.

4. Adjustments. As described in the report, the impact of a particular damage pattern can vary with conditions that are largely unrelated to the types of structural and nonstructural systems. Rough adjustments are made to account for three such conditions within the nonstructural criteria. Where one of the adjustments applies, the critical recovery objective for each relevant checklist item shifts by one recovery time category; where two apply, the critical objective shifts by two categories. This is illustrated below. The initial stage of evaluation should determine which adjustments, if any, should apply to the building or space being evaluated.

    - Size. This adjustment applies where the recovery time associated with a large building would be proportionately larger than the same damage pattern in a small building. Generally this applies to distributed nonstructural systems, but it can also apply to contents.

    - Public use. This adjustment applies where the degree of repair needed to restore functionality in a public space would be much greater than that needed to serve tenants willing to live with some unrepaired damage. Generally this relates to issues of habitability and legal compliance.

    - Contents. This adjustment applies where the functionality of a space relies disproportionately on specialized equipment or performance requirements.

5. Recovery objective. Informed by the previous points, the evaluator and client may select a recovery objective to guide the evaluation. Considering the functional recovery milestone, the recovery objective states the time by which basic building services are desired to recover as needed to support the building's (or space's) intended use, given the ASCE 31-level earthquake. If a clear objective is known, it can effectively reduce the scope of the evaluation. Otherwise, if no objective is specified, the evaluation should cover the full scope of the proposed checklists, and the results can be used to describe the expected recovery timeline.

THE EVALUATION STATEMENTS

The proposed criteria comprise three sets of Evaluation Statements (also called checklist items) excerpted from ASCE 31 for buildings in regions of high seismicity. In general, an item is required (that is, relevant to the resilience evaluation) if the damage pattern associated with it would compromise the recovery objective. Relevance to functional recovery is based on the judgments presented in the body of the report (and described briefly below). Relevance to reoccupancy is based on the relationship of each associated damage pattern to conditions that would be posted UNSAFE by ATC 20 (ATC, 1994).

Each required Evaluation Statement is to be marked with one of these notations:

C	Compliant
NC	Non-compliant
U	Unknown or not investigated
NA	Not applicable to the building or space in question

Ideally, a response of **C** or **NC** should be accompanied by a brief explanation of the basis for the finding (drawings, observation, analysis, etc.), including a statement regarding any judgment applied.

Geologic Site Hazards

The geotechnical criteria are the Geologic Site Hazards items from ASCE 31-03 section 3.8. All of the checklist items should be completed, regardless of the recovery objective. This is because the damage suggested by each of them could be severe enough to compromise even a relaxed objective allowing months for functional recovery.

For evaluations of reoccupancy, all of the checklist items should be completed because the associated damage patterns could be severe enough to result in an UNSAFE posting by ATC 20.

Structural

The structural criteria are a subset of the ASCE 31-03 Evaluation Statements for Life Safety evaluation in areas of high seismicity. Per ASCE 31-03 Table 3-2, those are the General Basic (B) and General Supplemental (S) checklists from ASCE 31-03 sections 3.7.16 and 3.7.16S. As described in the body of the report, reoccupancy and functional recovery require only that the structure remain stable and, at most, lightly damaged. More serious damage would not be expected in the absence of one or more critical deficiencies. Therefore, from the ASCE 31 Life Safety checklists, only the items related to the following critical conditions are required:

Deficiencies:
Material deterioration
Mass irregularity
Vertical discontinuity
Weak story
Soft story
Torsional irregularity
Low redundancy
Deflection incompatibility
Short captive column
Weak-column frames
Inadequate wall anchorage
Unbraced wood cripple walls
Precast without topping slab

Damage Patterns:
Partial or Total Collapse
Significant out-of-plumbness
Obvious severe damage

Structure Types:
Flat slab frames
Unreinforced masonry shear walls
Lift slab construction
Hillside wood-frame

While condition assessment is included in the structural criteria, the intent is primarily to prompt the evaluator to observe the condition of the structural elements in vulnerable or critical locations. It is expected that the deterioration would rarely be significant enough to cause or allow earthquake damage that would not otherwise occur. In those rare cases only should a material deterioration item be marked as non-compliant.

Evaluators who prefer the ASCE 31 structural checklists for specific building types may use those general and supplemental checklists from ASCE 31 sections 3.7.1 through 3.7.15, but need only consider the checklist items related to the critical conditions listed above.

Except where the building meets benchmark provisions, all the structural Evaluation Statements must be completed, regardless of the recovery objective. Again, this is because the damage suggested by each of them could be severe enough to compromise even a relaxed objective allowing months for functional recovery.

For evaluations of reoccupancy, all of the structural Evaluation Statements should be completed because the associated damage patterns could be severe enough to result in an UNSAFE posting by ATC 20.

Nonstructural

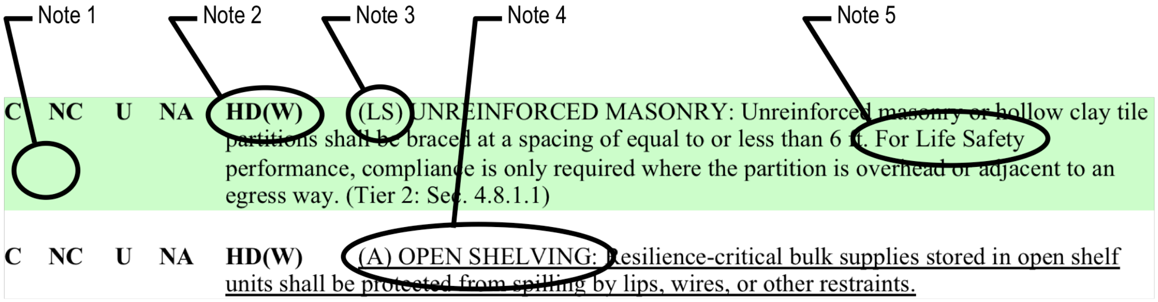
The nonstructural criteria are based on ASCE 31 requirements for Immediate Occupancy evaluation. Per ASCE 31-03 Table 3-2, in areas of high seismicity, those are the Basic (B), Intermediate (I), and Supplemental (S) checklists from ASCE 31-03 sections 3.9.1 through 3.9.3. For the next edition of ASCE 31, these will be reorganized into just two checklists, one for Life Safety (LS) evaluation, and one for Immediate Occupancy evaluation (IO) (ASCE, 2011). The proposed criteria use the anticipated reorganization. In addition, some checklist items not given in ASCE 31 have been added, based in part on FEMA E-74 (FEMA, 2011) guidance regarding vulnerable contents.

For nonstructural criteria, each checklist item is annotated to indicate the recovery objectives for which it is relevant. Relevance is related to the nature of the anticipated repair. The rationale for classifying each nonstructural checklist item is given in the body of the report. If the recovery objective is known prior to the evaluation, only the items relevant to that objective need to be considered. A statement marked "**HD**," for example, need only be considered for an objective of Hours or Days and may be ignored if the objective is Weeks or Months.

The checklist items are further annotated to account for the size, public use, and contents adjustments. A statement marked "**HD(W)**," for example, should be considered for a recovery objective of Hours or Days if no adjustments apply and should be considered for an objective of Hours, Days, or Weeks if one of the adjustments applies. Similarly, a statement marked "**HD(WM)**" should be checked for objectives up to Weeks if one adjustment applies and should be checked for objectives up to Months if two apply. In this way, the heightened significance of certain potential deficiencies effectively extends the expected recovery time.

For evaluations of reoccupancy, the critical time associated with each potential nonstructural deficiency is considered the same as for functional recovery, but many items are irrelevant. That is, the associated damage pattern might inhibit functionality but would not prevent an ATC 20 posting of INSPECTED. The reoccupancy-critical items are those associated with remaining falling hazards and with release of hazardous materials. They are shaded green in the checklists below. Thus, for evaluation of reoccupancy, only the green-shaded Evaluation Statements need be considered.

The following examples and notes explain the formatting of the nonstructural Evaluation Statements.



C	**NC**	**U**	**NA**	**HD(W)**	(LS) UNREINFORCED MASONRY: Unreinforced masonry or hollow clay tile partitions shall be braced at a spacing of equal to or less than 6 ft. For Life Safety performance, compliance is only required where the partition is overhead or adjacent to an egress way. (Tier 2: Sec. 4.8.1.1)
C	**NC**	**U**	**NA**	**HD(W)**	(A) OPEN SHELVING: Resilience-critical bulk supplies stored in open shelf units shall be protected from spilling by lips, wires, or other restraints.

1. Green shading means the UNREINFORCED MASONRY item is required for both evaluation of reoccupancy and evaluation of functional recovery. The lack of green shading means the OPEN SHELVING item is only required for evaluation of functional recovery.

2. **HD(W)** means the UNREINFORCED MASONRY item should be checked if the recovery objective is Hours or Days, provided none of the adjustments apply. The report indicates that for this item, the size adjustment might apply, presumably because similar partitions could exist throughout a large building. If the size adjustment applies, the item should be checked if the recovery objective is Hours, Days, or Weeks.

3. (LS) indicates that this Evaluation Statement comes from the anticipated ASCE 31 Life Safety checklist for buildings in regions of high seismicity.

4. The underscored text indicates this is an additional Evaluation Statement that does not appear in ASCE 31. The notation (A) indicates “additional.”

5. The sentence beginning “For Life Safety performance …” is a typical ASCE 31 waiver applicable to safety evaluation of certain conditions. For resilience evaluation, the waiver does not apply, so this sentence should be ignored.

GEOLOGIC SITE HAZARDS CRITERIA

Each of the following Geologic Site Hazards Evaluation Statements must be considered regardless of the recovery objective. Non-compliant (**NC**) conditions indicate potential damage likely to require months to recover supported functions.

When evaluating for reoccupancy, as opposed to functional recovery, all of the following Geologic Site Hazards Evaluation Statements should be considered. Non-compliant (**NC**) conditions indicate potential damage likely to require months for reoccupancy.

Geologic Site Hazards

C NC U NA (G) LIQUEFACTION: Liquefaction-susceptible, saturated, loose granular soils that could jeopardize the building's seismic performance shall not exist in the foundation soils at depths within 50 feet under the building. (Tier 2: Sec. 4.7.1.1)

C NC U NA (G) SLOPE FAILURE: The building site shall be sufficiently remote from potential earthquake-induced slope failures or rockfalls to be unaffected by such failures or shall be capable of accommodating any predicted movements without failure. (Tier 2: Sec. 4.7.1.2)

C NC U NA (G) SURFACE FAULT RUPTURE: Surface fault rupture and surface displacement at the building site is not anticipated. (Tier 2: Sec. 4.7.1.3)

STRUCTURAL CRITERIA

Each of the following Structural Evaluation Statements must be considered regardless of the recovery objective. Non-compliant (**NC**) conditions indicate potential damage likely to require months to recover supported functions.

When evaluating for reoccupancy, as opposed to functional recovery, all of the following Structural Evaluation Statements should be considered. Non-compliant (**NC**) conditions indicate potential damage likely to require months for reoccupancy.

When evaluating for either functionality or reoccupancy, if the structure is designed and constructed (or evaluated) in accordance with the benchmark provisions of ASCE 31 section 3.2, the structural system(s) may be deemed to satisfy an objective of Hours if benchmarked for Immediate Occupancy or Life Safety.

Building System: Configuration

C NC U NA (B) WEAK STORY: The strength of the lateral-force-resisting system in any story shall not be less than 80 percent of the strength in an adjacent story above or below. (Tier 2: Sec. 4.3.2.1)

C NC U NA (B) SOFT STORY: The stiffness of the lateral-force-resisting system in any story shall not be less than 70 percent of the lateral-force-resisting system stiffness in an adjacent story above or below, or less than 80% of the average lateral-force-resisting system stiffness of the three stories above or below. (Tier 2: Sec. 4.3.2.2)

C NC U NA (B) VERTICAL DISCONTINUITIES: All vertical elements in the lateral-force-resisting system shall be continuous to the foundation. (Tier 2: Sec. 4.3.2.4)

C NC U NA (B) MASS: There shall be no change in effective mass more than 50 percent from one story to the next. Light roofs, penthouses, and mezzanines need not be considered. (Tier 2: Sec. 4.3.2.5)

C NC U NA (B) TORSION: The estimated distance between the story center of mass and the story center of rigidity shall be less than 20 percent of the building width in either plan dimension. (Tier 2: Sec. 4.3.2.6)

Condition of Materials

(Minor edits relative to ASCE 31-03 not shown.)

C NC U NA (B) DETERIORATION OF WOOD: There shall be no evidence of or reason to suspect structural capacity loss due to decay, shrinkage, splitting, fire damage, or sagging in any of the wood members, or due to metal connection hardware being deteriorated, broken, or loose. (Tier 2: Sec. 4.3.3.1)

C NC U NA (B) DETERIORATION OF STEEL: There shall be no evidence of or reason to suspect structural capacity loss due to rusting, corrosion, cracking or other deterioration in any of the steel elements or connections in the vertical- or lateral-force-resisting systems. (Tier 2: Sec. 4.3.3.3)

C NC U NA (B) DETERIORATION OF CONCRETE: There shall be no evidence of or reason to suspect structural capacity loss due to deterioration of concrete or reinforcing steel in any of the vertical- or lateral-force-resisting elements. (Tier 2: Sec. 4.3.3.4)

C NC U NA (B) POST-TENSIONING ANCHORS: There shall be no evidence of corrosion or spalling in the vicinity of post-tensioning or end fittings. Coil anchors shall not have been used. (Tier 2: Sec. 4.3.3.5)

C NC U NA (B) PRECAST CONCRETE WALLS: There shall be no evidence of or reason to suspect structural capacity loss due to deterioration of concrete or reinforcing steel or evidence of distress, especially at the connections. (Tier 2: Sec. 4.3.3.6)

C NC U NA (B) MASONRY UNITS: There shall be no evidence of or reason to suspect structural capacity loss due to deterioration of masonry units. (Tier 2: Sec. 4.3.3.7)

C NC U NA (B) MASONRY JOINTS: The mortar shall not be easily scraped away from the joints by hand with a metal tool, and there shall be no evidence of or reason to suspect structural capacity loss due to areas of eroded mortar. (Tier 2: Sec. 4.3.3.8)

C NC U NA (B) CONCRETE WALL CRACKS: All existing diagonal cracks in wall elements shall be less than 1/8 inch, shall not be concentrated in one location, and shall not form an X pattern. (Tier 2: Sec. 4.3.3.9)

C NC U NA (B) REINFORCED MASONRY WALL CRACKS: All existing diagonal cracks in wall elements shall be less than 1/8 inch, shall not be concentrated in one location, and shall not form an X pattern. (Tier 2: Sec. 4.3.3.10)

C NC U NA (B) UNREINFORCED MASONRY WALL CRACKS: There shall be no existing diagonal cracks in wall elements greater than 1/8 inch or out-of-plane offsets in the bed joint greater than 1/8 inch, and any existing diagonal cracks shall not form an X pattern. (Tier 2: Sec.4.3.3.11)

C NC U NA (B) CRACKS IN INFILL WALLS: There shall be no existing diagonal cracks in the infilled walls that extend throughout a panel greater than 1/8 inch, or out-of-plane offsets in the bed joint greater than 1/8 inch. (Tier 2: Sec. 4.3.3.12)

C NC U NA (B) CRACKS IN BOUNDARY COLUMNS: There shall be no existing diagonal cracks wider than 1/8 inch in concrete columns that encase masonry infills. (Tier 2: Sec. 4.3.3.13)

Seismic Force Resisting System: Moment Frames

C NC U NA (B) REDUNDANCY: The number of lines of moment frames in each principal direction shall be greater than or equal to 2. The number of bays of moment frames in each line shall be greater than or equal to 2. (Tier 2: Sec. 4.4.1.1.1)

C NC U NA (B) INTERFERING WALLS: All concrete and masonry infill walls ~~placed~~ in moment frames shall be isolated from structural elements. (Tier 2: Sec. 4.4.1.2.1)

Steel Moment Frames

C NC U NA (S) STRONG COLUMN/WEAK BEAM: The percentage of strong column/weak beam joints in each story of each line of moment-resisting frames shall be greater than 50 percent. (Tier 2: Sec. 4.4.1.3.6)

Concrete Moment Frames

C NC U NA (S) FLAT SLAB FRAMES: The lateral-force-resisting system shall not be a frame consisting of columns and a flat slab/plate without beams. (Tier 2: Sec. 4.4.1.4.3)

C NC U NA (S) CAPTIVE COLUMNS: There shall be no columns at a level with height/depth ratios less than 50 percent of the nominal height/depth ratio of the typical columns at that level. (Tier 2: Sec. 4.4.1.4.5)

C NC U NA (S) NO SHEAR FAILURES: The shear capacity of frame members shall be able to develop the moment capacity at the ends of the members. (Tier 2: Sec. 4.4.1.4.6)

C NC U NA (S) STRONG COLUMN/WEAK BEAM: The sum of the moment capacity of the columns shall be 20 percent greater than that of the beams at frame joints. (Tier 2: Sec. 4.4.1.4.7)

Seismic Force Resisting System: Shear Walls

C NC U NA (B) REDUNDANCY: The number of lines of shear walls in each principal direction shall be greater than or equal to 2. (Tier 2: Sec. 4.4.2.1.1)

Unreinforced Masonry Shear Walls

C NC U NA (B) SHEAR STRESS CHECK: The shear stress in the unreinforced masonry shear walls, calculated using the Quick Check procedure of Section 3.5.3.3, shall be less than 30 psi for clay units and 70 psi for concrete units. (Tier 2: Sec. 4.4.2.5.1)

C NC U NA (S) PROPORTIONS: The height-to-thickness ratio of the shear walls at each story shall be less than the following (Tier 2: Sec. 4.4.2.5.2):

Top story of multi-story building: 9
First story of multi-story building: 15
All other conditions: 13

Wood-Frame Shear Walls

C NC U NA (B) HILLSIDE SITE: For structures that are taller on at least one side by more than one-half story due to a sloping site, all shear walls on the downhill ~~slope~~ side shall have a height-to-width ratio less than 1-to-1. (Tier 2: Sec. 4.4.2.7.6)

C NC U NA (B) CRIPPLE WALLS: Cripple walls below first-floor-level shear walls shall be braced to the foundation with wood structural panels and anchor bolts. (Tier 2: Sec. 4.4.2.7.7)

Seismic Force Resisting System: Braced Frames

C NC U NA (B) REDUNDANCY: The number of lines of braced frames in each principal direction shall be greater than or equal to 2. The number of braced bays in each required line shall be greater than 2. (Tier 2: Sec. 4.4.3.1.1)

Frames Not Part of the Lateral-Force-resisting System

C NC U NA (S) DEFLECTION COMPATIBILITY: Secondary components shall have the shear capacity to develop the flexural strength of the components. (Tier 2: Sec. 4.4.1.6.2.)

C NC U NA (S) FLAT SLABS: Flat slabs/plates not part of the lateral-force-resisting system shall have continuous bottom steel through the column joints. (Tier 2: Sec. 4.4.1.6.2.)

Diaphragms

C NC U NA (B) TOPPING SLAB: Precast concrete diaphragm elements shall be interconnected by a continuous reinforced concrete topping slab. (Tier 2: Sec. 4.5.5.1)

C NC U NA (A) LIFT SLAB CONSTRUCTION: The structure shall not have been erected with lift slab construction.

Connections

C NC U NA (B) WALL ANCHORAGE: Exterior concrete or masonry walls that are dependent on the diaphragm for out-of-plane support shall be anchored for out-of-plane forces at each diaphragm level with steel anchors, reinforcing dowels, or straps that are developed into the diaphragm. Connections shall have adequate strength to resist the connection force calculated in the Quick Check procedure of Section 3.5.3.7. (Tier 2: Sec. 4.6.1.1)

C NC U NA (B) WOOD LEDGERS: The connection between the wall panels and the diaphragm shall not induce cross-grain bending or tension in the wood ledgers. (Tier 2: Sec. 4.6.1.2)

C NC U NA (S) PRECAST PANEL CONNECTIONS: There shall be at least two anchors from each precast wall panel into the diaphragm elements. (Tier 2: Sec. 4.6.1.3)

C NC U NA (B) TOPPING SLAB TO WALLS OR FRAMES: Reinforced concrete topping slabs that interconnect the precast concrete diaphragm elements shall be doweled for transfer of forces into the shear wall or frame elements. (Tier 2: Sec. 4.6.2.3)

C NC U NA (B) WOOD SILLS: All wood sills shall be bolted to the foundation. (Tier 2: Sec. 4.6.3.4)

C NC U NA (S) WOOD SILL BOLTS: Sill bolts shall be spaced at 6 feet or less, with proper edge distance and end distance provided for wood and concrete. (Tier 2: Sec. 4.6.3.9)

C NC U NA (B) GIRDER/COLUMN CONNECTION: There shall be a positive connection utilizing plates, connection hardware, or straps between the girder and the column support. (Tier 2: Sec. 4.6.4.1)

C NC U NA (S) GIRDERS: Girders supported by walls or pilasters shall have at least two ties securing the anchor bolts. (Tier 2: Sec. 4.6.4.2)

C NC U NA (S) CORBEL BEARING: If the frame girders bear on column corbels, the length of bearing shall be greater than 3 inches. (Tier 2: Sec. 4.6.4.3)

C NC U NA (S) CORBEL CONNECTIONS: The frame girders shall not be connected to corbels with welded elements. (Tier 2: Sec. 4.6.4.4)

C NC U NA (S) BEAM, GIRDER, AND TRUSS SUPPORTS: Beams, girders, and trusses supported by unreinforced masonry walls or pilasters shall have independent secondary columns for support of vertical loads. (Tier 2: Sec. 4.6.4.1)

NONSTRUCTURAL CRITERIA

Each of the following Nonstructural Evaluation Statements must be considered where the recovery objective is noted at the start of the statement. For example, a statement noted **HD** must be completed where the recovery objective is Hours or Days but need not be completed where the recovery objective is Weeks or Months. Objectives noted in parentheses must also be considered if one or more of the exacerbating adjustments (Size, Public Use, or Contents) applies.

When evaluating for reoccupancy, as opposed to functional recovery, only the green-shaded Nonstructural Evaluation Statements need be considered.

Condition Assessment

C NC U NA HD(W) (LS) DETERIORATION (Cladding and Glazing): There shall be no evidence of or reason to suspect deterioration, damage, or corrosion in any of the connection elements. (Tier 2: Sec. 4.8.4.2)

C NC U NA HD(W) (LS) DETERIORATION (Masonry Veneer): There shall be no evidence of or reason to suspect deterioration, damage, or corrosion in any of the connection elements. (Tier 2: Sec. 4.8.5.4)

C NC U NA HDWM (LS) HAZARDOUS MATERIAL EQUIPMENT: HVAC or other equipment containing hazardous material shall not have damaged supply lines. (Tier 2: Sec. 4.8.12.2)

C NC U NA HD(W) (IO) MORTAR (Masonry Veneer): The mortar in masonry veneer shall not be easily scraped away from the joints by hand with a metal tool, and there shall not be significant areas of eroded mortar. (Tier 2: Sec. 4.8.5.5)

C NC U NA HD(W) (IO) STONE CRACKS (Masonry Veneer): There shall no be visible cracks or signs of visible distortion in the stone. (Tier 2: Sec. 4.8.5.7)

C NC U NA HD(W) (IO) WEEP HOLES (Masonry Veneer): In veneer braced by stud walls, functioning weep holes and base flashing shall be present. (Tier 2: Sec. 4.8.5.6)

C NC U NA HDW(M) (LS) DETERIORATION (Equipment): There shall be no evidence of or reason to suspect deterioration, damage, or corrosion in any of the anchorage or supports of mechanical or electrical equipment. (Tier 2: Sec. 4.8.12.3)

Life Safety Systems

C NC U NA HDW(M) (LS) EMERGENCY LIGHTING: Emergency and egress lighting equipment shall be anchored or braced to prevent falling during an earthquake and maintain operation afterward. (Tier 2: Sec. 4.8.3.1)

C NC U NA HDW(M) (LS) EMERGENCY POWER: Equipment used to power or control life safety systems shall be mounted to maintain operation after an earthquake. (Tier 2: Sec. 4.8.12.1)

C NC U NA HDWM (LS) FIRE SUPPRESSION PIPING: Fire suppression piping shall be anchored and braced in accordance with NFPA-13 (NFPA, ~~1996~~ 2010). (Tier 2: Sec. 4.8.13.1)

C NC U NA HDWM (LS) FLEXIBLE COUPLINGS: Fire suppression piping shall have flexible couplings. (Tier 2: Sec. 4.8.13.2)

C NC U NA HDW(M) (LS) STAIR AND SMOKE DUCTS: Stair pressurization and smoke control ducts shall be braced and shall have flexible connections at seismic joints. (Tier 2: Sec. 4.8.14.1)

Hazardous Materials

C NC U NA HDWM (LS) TOXIC SUBSTANCES: Toxic and hazardous substances stored in breakable containers shall be restrained from falling by latched doors, shelf lips, wires, or other methods. (Tier 2: Sec. 4.8.15.1)

C NC U NA HDWM (IO) GAS CYLINDERS: Compressed gas cylinders shall be restrained. (Tier 2: Sec. 4.8.15.2)

C NC U NA HDWM (IO) SHUT-OFF VALVES: Piping containing hazardous materials, including natural gas and high-temperature energy, shall have shut-off valves or other devices to prevent major spills or leaks. (Tier 2: Sec. 4.8.13.4, 4.8.15.3)

C NC U NA HDW(M) (LS) HAZARDOUS MATERIAL EQUIPMENT: HVAC or other equipment containing hazardous material shall not have unbraced isolation supports.

C NC U NA HDWM (LS) FLEXIBLE COUPLINGS: Hazardous material piping, including natural gas piping, shall have flexible couplings. (Tier 2: Sec. 4.8.13.2)

Partitions

C NC U NA HD(W) (LS) UNREINFORCED MASONRY: Unreinforced masonry or hollow clay tile partitions shall be braced at a spacing of equal to or less than 6 ft. For Life Safety performance, compliance is only required where the partition is overhead or adjacent to an egress way. (Tier 2: Sec. 4.8.1.1)

C NC U NA HD(W) (LS) URM WALLS: Walls around stair enclosures shall not consist of unbraced hollow clay tile or unreinforced masonry with a height-to-thickness ratio greater than 12-to-1. (Tier 2: Sec. 4.8.10.1)

C NC U NA HD(W) (IO) DRIFT: Rigid cementitious partitions shall be detailed to accommodate a drift ratio of 0.02 in steel moment frame, concrete moment frame, and wood frame buildings. Rigid cementitious partitions shall be detailed to accommodate a drift ratio of 0.005 in other buildings. (Tier 2: Sec. 4.8.1.2)

C NC U NA HD(W) (LS) SUPPORT: The integrated suspended ceiling system shall not be used to laterally support the tops of gypsum board, masonry, or hollow clay tile partitions. For Life Safety performance, compliance is only required where the partition is overhead or adjacent to an egress way. (Tier 2: Sec. 4.8.2.1)

C NC U NA H(D) (IO) STRUCTURAL SEPARATIONS: Partitions at structural separations shall have seismic or control joints. (Tier 2: Sec. 4.8.1.3)

C NC U NA HD(W) (IO) TOPS: The tops of framed or panelized partitions (i.e. modular furniture) that only extend to the ceiling line shall have lateral bracing to the building structure at a spacing equal to or less than 6 feet. (Tier 2: Sec. 4.8.1.4)

Ceilings

C NC U NA H(D) (LS) INTEGRATED CEILINGS: Integrated suspended ceilings at exits and corridors weighing more than 2 pounds per square foot shall be laterally restrained with a minimum of four diagonal wires or rigid members attached to the structure above at a spacing of equal to or less than 12 ft. (Tier 2: Sec. 4.8.2.3)

C NC U NA HD(W) (LS) SUSPENDED LATH AND PLASTER: Ceilings consisting of suspended lath and plaster or gypsum board shall be attached to resist seismic forces for every 12 square feet of area. (Tier 2: Sec. 4.8.2.4)

C NC U NA H(D) (LS) LAY-IN TILES: Lay-in tiles used in ceiling panels located at exits and corridors shall be secured with clips. (Tier 2: Sec. 4.8.2.2)

C NC U NA (H) (IO) EDGES: The edges of integrated suspended ceilings shall be separated from enclosing walls by a minimum of 1/2 inch. (Tier 2: Sec. 4.8.2.5)

C NC U NA (H) (IO) SEISMIC JOINT: The ceiling system shall not extend continuously across any seismic joint. (Tier 2: Sec. 4.8.2.6)

Light Fixtures

C NC U NA HDW(M) (LS) INDEPENDENT SUPPORT: Light fixtures in suspended grid ceilings shall be supported independently of the ceiling suspension system by a minimum of two wires at diagonally opposite corners of the fixtures. (Tier 2: Sec. 4.8.3.2)

C NC U NA H(D) (IO) LENS COVERS: Lens covers on light fixtures shall be attached or supplied with safety devices. (Tier 2: Sec. 4.8.3.4)

C NC U NA HDW(M) (IO) PENDANT SUPPORTS: Light fixtures on pendant supports shall be attached at a spacing equal to or less than 6 feet and, if rigidly supported, shall be free to move with the structure to which they are attached without damaging adjoining materials. (Tier 2: Sec. 4.8.3.3)

C NC U NA HDW(M) (A) OTHER LIGHT FIXTURES: Light fixtures other than emergency lighting, pendant fixtures, or ceiling-integrated luminaires are attached or restrained as needed to serve the performance objective.

Cladding and Glazing

C NC U NA HD(W) (LS) CLADDING ANCHORS: Cladding components weighing more than 10 psf shall be mechanically anchored to the exterior wall framing at a spacing equal to or less than 4 ft. For Life Safety performance, compliance is only required where the cladding is overhead or adjacent to an egress way. (Tier 2: Sec. 4.8.4.1)

C NC U NA HD(W) (LS) CLADDING ISOLATION: For moment frame buildings of steel or concrete, panel connections shall be detailed to accommodate a story drift ratio of 0.02. For Life Safety performance, compliance is only required where the cladding is overhead or adjacent to an egress way. (Tier 2: Sec. 4.8.4.3)

C NC U NA HD(W) (LS) MULTI-STORY PANELS: For multistory panels attached at each floor level, panel connections shall be detailed to accommodate a story drift ratio of 0.02. For Life Safety performance, compliance is only required where the cladding is overhead or adjacent to an egress way. (Tier 2: Sec. 4.8.4.4)

C NC U NA HD(W) (LS) PANEL CONNECTIONS: Exterior cladding panels shall be anchored out-of-plane with a minimum of 4 connections for each wall panel. For Life Safety performance, compliance is only required where the cladding is overhead or adjacent to an egress way. (Tier 2: Sec. 4.8.4.7)

C NC U NA HD(W) (LS) BEARING CONNECTIONS: Where bearing connections are required, there shall be a minimum of two bearing connections for each wall panel. For Life Safety performance, compliance is only required where the cladding is overhead or adjacent to an egress way. (Tier 2: Sec. 4.8.4.5)

C NC U NA HD(W) (LS) INSERTS: Where inserts are used in concrete connections, the inserts shall be anchored to reinforcing steel or other positive anchorage. For Life Safety performance, compliance is only required where the cladding is overhead or adjacent to an egress way. (Tier 2: Sec. 4.8.4.6)

C NC U NA HD(W) (LS) OVERHEAD GLAZING: Glazing in curtain walls, skylights, interior glass partitions, etc. and individual panes over 16 square feet in area, located up to a height of 10 feet above an egress way or occupiable space, shall have safety glazing. Such glazing located more than 10 feet above an egress way or occupiable space shall be laminated annealed or laminated heat-strengthened safety glass or other glazing system that will remain in the frame when glass is cracked. (Tier 2: Sec. 4.8.4.8)

C NC U NA HD(W) (IO) GLAZING RESTRAINT: Exterior glazing shall be laminated annealed or laminated heat-strengthened safety glass or other glazing system that will remain in the frame when glass is cracked. (Tier 2: Sec. 4.8.4.9)

C NC U NA HD(W) (A) GLAZING FUNCTIONALITY: Glazing and window or storefront framing that would compromise building security, weather resistance, or post-earthquake usability if damaged shall have adequate deformation resistance.

Masonry Veneer

C NC U NA HD(W) (LS) SHELF ANGLES: Masonry veneer shall be supported by shelf angles or other elements at each floor above the first floor. For Life Safety performance, compliance is only required where the cladding is overhead or adjacent to an egress way. (Tier 2: Sec. 4.8.5.1)

C NC U NA HD(W) (LS) WEAKENED PLANES: Masonry veneer shall be anchored to the back-up adjacent to weakened planes, such as at the locations of flashing. (Tier 2: Sec. 4.8.5.3)

C NC U NA HD(W) (LS) TIES: Masonry veneer shall be connected to the back-up with corrosion-resistant ties. The ties shall have a spacing of equal to or less than 24 inches with a minimum of one tie for every 2-2/3 square feet. For Life Safety performance, compliance is only required where the cladding is overhead or adjacent to an egress way. (Tier 2: Sec. 4.8.5.2)

C NC U NA HD(W) (IO) STUD TRACKS (Metal stud back-up): Stud tracks shall be fastened to structural framing at a spacing equal to or less than 24 inches on center. (Tier 2: Sec. 4.8.6.1)

C NC U NA HD(W) (IO) OPENINGS (Metal stud back-up): Steel studs shall frame window and door openings. (Tier 2: Sec. 4.8.6.2)

C NC U NA HD(W) (IO) ANCHORAGE (Masonry stud back-up): Back-up shall have a positive anchorage to the structural framing at a spacing equal to or less than 4 feet along the floors and roof. (Tier 2: Sec. 4.8.7.1)

C NC U NA HD(W) (IO) URM BACK-UP (Masonry stud back-up): There shall be no unreinforced masonry back-up. (Tier 2: Sec. 4.8.7.2)

Parapets, Cornices, Ornamentation and Appendages

C NC U NA HD (LS) URM PARAPETS: There shall be no laterally unsupported unreinforced masonry parapets or cornices with height-to-thickness ratios greater than 1.5. (Tier 2: Sec. 4.8.8.1)

C NC U NA HD (LS) CANOPIES: Canopies located at building exits shall be anchored to the structural framing at a spacing of 6 feet or less. (Tier 2: Sec. 4.8.8.2)

C NC U NA HD (LS) CONCRETE PARAPETS: Concrete parapets with height-to-thickness ratios greater than 2.5 shall have vertical reinforcement. (Tier 2: Sec. 4.8.8.3)

C NC U NA HD (LS) APPENDAGES: Cornices, parapets, signs, and other appendages that extend above the highest point of anchorage to the structure or cantilever from exterior wall faces and other exterior wall ornamentation shall be reinforced and anchored to the structural system at a spacing equal to or less than 6 feet. This evaluation statement does not apply to parapets or cornices covered by other evaluation statements. For Life Safety performance, compliance is only required where the appendage is overhead or adjacent to an egress way. (Tier 2: Sec. 4.8.8.4)

C NC U NA HD (A) TILE ROOFING: Tile roofing that could pose a falling hazard if dislodged shall be adequately attached.

C NC U NA HD (A) ADJACENT APPURTENANCES: Adequate separations, joints, or details shall be provided between the main building and adjacent elements that serve it (e.g. pedestrian bridges, porte cochere, etc.)

C NC U NA HD (A) ADJACENT BUILDINGS: Adjacent properties do not present any damageable conditions that would compromise the performance of the subject building.

Masonry Chimneys

C NC U NA HD (LS) URM CHIMNEYS: No unreinforced masonry chimney shall extend above the roof surface more than twice the least dimension of the chimney. (Tier 2: Sec. 4.8.9.1)

C NC U NA HD (LS) ANCHORAGE: Masonry chimneys shall be anchored at each floor level, at the topmost ceiling level, and at the roof. (Tier 2: Sec. 4.8.9.2)

Stairs

C NC U NA HDW(M) (LS) STAIR DETAILS: In moment frame structures, the connection between the stairs and the structure shall not rely on shallow anchors in concrete. Alternatively, the stair details shall be capable of accommodating the drift calculated using the Quick Check procedure of Section 3.5.3.1 without including tension in the anchors. (Tier 2: Sec. 4.8.10.2)

Building Contents and Furnishing

C NC U NA H(DW) (LS) TALL NARROW CONTENTS: Contents over 4 feet in height with a height-to-depth or height-to-width ratio greater than 3-to-1 shall be anchored to the floor slab or adjacent structural walls. For Life Safety performance, compliance is only required where the cladding is overhead or adjacent to an egress way. (Tier 2: Sec. 4.8.11.1)

C NC U NA H(DW) (A) OPEN SHELVING: Resilience-critical bulk supplies stored in open shelf units shall be protected from spilling by lips, wires, or other restraints.

C NC U NA HD(WM) (A) PALLET RACKS: Pallet racks shall be anchored to the floor slab and shall not be loaded beyond their manufacturer-recommended capacity. In addition, resilience-critical bulk supplies stored on pallet racks shall be protected from fall-through and toppling by decking, blocking of pallet loads, or other restraints.

C NC U NA HDW(M) (IO) ACCESS FLOORS: Access floors over 9 inches in height that support resilience-critical equipment shall be braced. (Tier 2: Sec. 4.8.11.4)

C NC U NA HDW(M) (IO) EQUIPMENT ON ACCESS FLOORS: Resilience-critical equipment and computers supported on access floor systems shall be either attached to the structure or fastened to a laterally braced floor system. (Tier 2: Sec. 4.8.11.5)

C NC U NA (HD) (IO) FILE CABINETS: File cabinets arranged in groups shall be attached to one another. (Tier 2: Sec. 4.8.11.2)

C NC U NA (HD) (IO) CABINET DOORS AND DRAWERS: Cabinet doors and drawers shall have latches to keep them closed during an earthquake. (Tier 2: Sec. 4.8.11.3)

C NC U NA H(DW) (A) OWNER-FURNISHED EQUIPMENT: Resilience-critical equipment not built-in with the original construction, and largely generic (including typical office equipment, small appliances, potted plants, artwork, security cameras and monitors, suspended AV and IT equipment, etc.) shall be anchored, restrained, or otherwise protected from damaging themselves or adjacent resilience-critical items. (For larger, customized, or specialty equipment, see PROCESS EQUIPMENT, etc.)

C NC U NA HDWM (A) COMMUNICATIONS EQUIPMENT: Resilience-critical communications equipment (rack-mounted equipment, satellite dishes, antennae, etc. etc.) shall be anchored, restrained, or otherwise protected from damaging themselves or adjacent resilience-critical items.

C NC U NA HDWM (A) PROCESS EQUIPMENT: Resilience-critical process equipment, whether floor-mounted or suspended (piping, conveyors, tanks, ovens, dedicated plumbing or HVAC systems, etc.) shall be anchored, restrained, or otherwise protected from damaging themselves or adjacent resilience-critical items.

C NC U NA HDWM (A) PROCESS POWER EQUIPMENT: Equipment used to power, control, or support resilience-critical functions (including battery racks, emergency generators, day tanks, exhaust ducts, control panels, cooling systems, etc.) shall be mounted to maintain operation after an earthquake.

Mechanical and Electrical Equipment

C NC U NA H (A) GAS-FIRED WATER HEATERS: Gas-fired water heaters shall be braced to adjacent walls. (This Evaluation Statement is about damage to typical small tanks. Gas piping and shut-offs are addressed under Hazardous Materials.)

C NC U NA (H) (A) ROOF-MOUNTED SOLAR PANELS: Roof-mounted solar panels shall be adequately anchored, braced, or otherwise protected against damage. (This Evaluation Statement presumes that solar panels are not the sole energy source for the building.)

C NC U NA HDW(M) (A) TANKS: Structurally mounted tanks shall be adequately anchored, braced or restrained from overturning or excessive sliding. (See Hazardous Materials and Piping for related provisions.)

C NC U NA HDW(M) (LS) ATTACHED EQUIPMENT: Equipment weighing over 20 lb that is attached to ceilings, walls, or other supports 4 feet above the floor level shall be braced. For Life Safety performance, compliance is only required where the equipment is overhead or adjacent to an egress way. (Tier 2: Sec. 4.8.12.4)

C NC U NA HDW(M) (LS) VIBRATION ISOLATORS: Equipment mounted on vibration isolators shall be equipped with restraints or snubbers. For Life Safety performance, compliance is only required where the equipment is overhead or adjacent to an egress way. (Tier 2: Sec. 4.8.12.5)

C NC U NA HDW(M) (IO) ELECTRICAL EQUIPMENT: Electrical equipment and associated wiring shall be laterally braced to the structural system. (Tier 2: Sec. 4.8.12.7)

C NC U NA HDW(M) (IO) DOORS: Mechanically operated doors shall be detailed to operate at a story drift ratio of 0.01 unless manual operation is also possible. (Tier 2: Sec. 4.8.12.8)

C NC U NA H(DW) (IO) HEAVY EQUIPMENT: Equipment weighing over 100 pounds shall be anchored to the structure or foundation. (Tier 2: Sec. 4.8.12.6)

Piping

C NC U NA HDW(M) (A) SPRINKLER HEADS: Where they pass through ceilings or partitions, pressurized sprinkler heads shall have clearance in accordance with NFPA-13 (NFPA, 2007).

C NC U NA HDW(M) (LS) FLEXIBLE COUPLINGS: Fluid piping shall have flexible couplings. (Tier 2: Sec. 4.8.13.2)

C NC U NA HDW(M) (A) PENETRATIONS AND SEPARATIONS: Fluid and gas piping shall have adequate clearance or seismic joints where it passes through walls, floors, between structures, etc.

C NC U NA HDW(M) (IO) FLUID PIPING: Fluid piping shall be anchored and braced to the structure to prevent breakage in piping. (Tier 2: Sec. 4.8.13.3)

C NC U NA HD(W) (IO) C-CLAMPS: One-sided C-clamps that support piping greater than 2.5 inches in diameter shall be restrained. (Tier 2: Sec. 4.8.13.5)

Ducts

C NC U NA HDW(M) (IO) DUCT BRACING: For ductwork providing resilience-critical HVAC, rectangular ductwork exceeding 6 square feet in cross-sectional area, and round ducts exceeding 28 inches in diameter, shall be braced. Maximum spacing of transverse bracing shall not exceed 30 feet. Maximum spacing of longitudinal bracing shall not exceed 60. Intermediate supports shall not be considered part of the lateral-force-resisting system. (Tier 2: Sec. 4.8.14.2)

C NC U NA HDW(M) (IO) DUCT SUPPORT: Ducts shall not be supported by piping or electrical conduit. (Tier 2: Sec. 4.8.14.3)

Elevators

Elevators need only be considered if they are necessary for a resilience-critical occupancy. The critical objectives shown are based on presumed damage, not on the shorter time necessary (even for a compliant elevator) to have the elevator inspected and put back into service after its earthquake sensors automatically stopped it. The final Evaluation Statement, GO-SLOW ELEVATORS, conservatively reflects the time to reactivate (see ASCE 31 C4.8.16.9).

C NC U NA HDW(M) (S) SUPPORT SYSTEM: All elements of the elevator system shall be anchored. (Tier 2: Sec. 4.8.16.1)

C NC U NA HDW(M) (S) SEISMIC SWITCH: All elevators shall be equipped with seismic switches that will terminate operations when the ground motion exceeds 0.10g. (Tier 2: Sec. 4.8.16.2)

C NC U NA HDW(M) (S) SHAFT WALLS: All elevator shaft walls shall be anchored and reinforced to prevent toppling into the shaft during strong shaking. (Tier 2: Sec. 4.8.16.3)

C NC U NA HDW(M) (S) RETAINER GUARDS: Cable retainer guards on sheaves and drums shall be present to inhibit the displacement of cables. (Tier 2: Sec. 4.8.16.4)

C NC U NA HDW(M) (S) RETAINER PLATE: A retainer plate shall be present at the top and bottom of both car and counterweight. (Tier 2: Sec. 4.8.16.5)

C NC U NA HDW(M) (S) COUNTERWEIGHT RAILS: All counterweight rails and divider beams shall be sized in accordance with ASME A17.1. (Tier 2: Sec. 4.8.16.6)

C NC U NA HDW(M) (S) BRACKETS: The brackets that tie the car rails and the counterweight rail to the building structure shall be sized in accordance with ASME A17.1. (Tier 2: Sec. 4.8.16.7)

C NC U NA HDW(M) (S) SPREADER BRACKET: Spreader brackets shall not be used to resist seismic forces. (Tier 2: Sec. 4.8.16.8)

C NC U NA HDW(M) (S) GO-SLOW ELEVATORS: The building shall have a go-slow elevator system. (Tier 2: Sec. 4.8.16.9)