Standard Guide for Seismic Risk Assessment of Buildings[1]

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INTRODUCTION

Lenders, insurers, and equity owners in real estate are giving more intense scrutiny to earthquake risk than ever before. The 1989 Loma Prieta, California earthquake, which caused more than $6 billion in damage, accelerated the trend toward considering loss estimation in real estate transactions. The 1994 Northridge, California earthquake, with over $20 billion in damage, made seismic risk assessment an integral part of real estate financial decision-making for regions at risk of damaging earthquakes. Users of Seismic Risk Assessment reports need specific and consistent measures for assessing the possibility of future loss due to earthquake occurrences. This guide discusses specific approaches that the real estate and technical communities can consider a basis for characterizing the seismic risk assessment of buildings in an earthquake. It uses two concepts to characterize earthquake loss: probable loss (PL) and scenario loss (SL). Use of the term probable maximum loss (PML) is acceptable, provided it is specifically and adequately defined by the User.

1. Scope

1.1 This guide provides guidance on conducting seismic risk assessments for buildings. As such, this guide assists a User to assess a property's potential for losses from earthquake occurrences.

1.1.1 Hazards addressed in this guide include:

1.1.1.1 Earthquake ground shaking,

1.1.1.2 Earthquake-caused site instability, including fault rupture, landslides, soil liquefaction, lateral spreading and settlement, and

1.1.1.3 Earthquake-caused off-site response impacting the property, including flooding from dam or dike failure, tsunamis and seiches.

1.1.2 This guide does not address the following:

1.1.2.1 Earthquake-caused fires and toxic materials releases.

1.1.2.2 Federal, state, or local laws and regulations of building construction or maintenance. Users are cautioned that current federal, state, and local laws and regulations may differ from those in effect at the time of the original construction of the building(s).

1.1.2.3 Preservation of life safety.

1.1.2.4 Prevention of building damage.

1.1.2.5 Contractual and legal obligations between prior and subsequent Users of seismic risk assessment reports or between Providers who prepared the report and those who would like to use such prior reports.

1.1.2.6 Contractual and legal obligations between a Provider and a User, and other parties, if any.

1.1.3 It is the responsibility of the User of this guide to establish appropriate life safety and damage prevention practices and determine the applicability of current regulatory limitations prior to use.

1.2 The objectives of this guide are:

1.2.1 To synthesize and document guidelines for seismic risk assessment of buildings;

1.2.2 To encourage standardized seismic risk assessments;

1.2.3 To establish guidelines for field observations of the site and physical conditions, and the document review and research considered appropriate, practical, sufficient, and reasonable for seismic risk assessment;

1.2.4 To establish guidelines on what reasonably can be expected of and delivered by a Provider in conducting the seismic risk assessment of buildings; and

1.2.5 To establish guidelines by which a Provider can communicate to the User observations, opinions, and conclusions in a manner that is meaningful and not misleading either by content or by omission.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

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2. Referenced Documents

2.1 *ASTM Standards:*[2]

E631 Terminology of Building Constructions

2.2 *ICC Standard:*[3]

IBC International Building Code, current edition

2.3 *Other References*—The following resource documents provide technical guidance for the seismic evaluation and retrofit of existing buildings:[4]

ASCE 7-10 Minimum Design Loads for Buildings and Other Structures

ASCE 31 Seismic Evaluation of Existing Buildings[5]

ASCE 41-13 Seismic Evaluation and Retrofit of Existing Buildings[6]

3. Terminology

3.1 *Definitions:*

3.1.1 See Terminology E631.

3.1.2 For definition of terms related to building construction, ASCE 31 and ASCE 41 provide additional resources for understanding terminology and language related to seismic performance of buildings.

3.1.3 For definition of terms and additional detailed information on concepts related to seismic events and structural design, see references at the end of this document.

3.2 *Definitions of Terms Specific to This Standard*—This section provides definitions of concepts and terms specific to this guide. The concepts and terms are an integral part of this guide and are critical to an understanding of this guide and its use.

3.2.1 *active earthquake fault, n*—an earthquake fault that has exhibited surface displacement within Holocene time typically about the last 11 000 years.

3.2.2 *building code, n*—a collection of laws (regulations, ordinances, or statutory requirements) applicable to buildings, adopted by governmental (legislative) authority and administered with the primary intent of protecting public health, safety, and welfare.

3.2.3 *building systems, n*—all physical systems that comprise a building and its services.

3.2.3.1 *Discussion*—This includes architectural, structural, mechanical, plumbing, electrical, fire life-safety, vertical transportation and security systems. More specifically architectural systems include non-structural building envelopes, roofing, ceilings, partitions, non-structural demising walls etc; structural systems include both gravity and seismic force-resisting systems and foundations; mechanical systems include heating, ventilating and air conditioning equipment, ducts, control systems etc; plumbing systems include domestic water heaters, piping, controls, plumbing fixtures, waste water system piping and natural gas or propane systems, storm water drains and pumps etc; electrical systems include switchgear, transformers, breakers, wiring, lighting fixtures, emergency power systems etc; and fire life-safety systems include fire sprinkler systems, monitoring and alarm systems etc. Not included in building systems are those contained within a building and defined as contents.

3.2.4 *business interruption, n*—a period of interruption to normal business operations that can potentially or materially cause a loss to the owner/operator of that business through loss of use of the building until use is restored consistent with business operations.

3.2.4.1 *Discussion*—The loss may be partial or total for the period under consideration. Business interruption is expressed in days/weeks/months of downtime for the building as a whole or the equivalent operating value.

3.2.5 *construction documents, n*—documents used in the initial construction phase and any subsequent modification(s) of building(s) for which the seismic risk assessment is prepared. Construction documents include drawings, calculations, specifications, geotechnical reports, construction reports, and testing results.

3.2.5.1 *Discussion*—Generally as-built plans are the preferred form of construction documents.

3.2.6 *contents, n*—elements contained within the building that are not defined as building systems.

3.2.6.1 *Discussion*—Examples include tenant-installed equipment, storage racks, material handling systems, shelving, stored inventories, furniture, fixtures, office machines, computer equipment, filing cabinets, and personal property.

3.2.7 *correlation, n*—the tendency or likelihood of the behavior of one element to be influenced by the known behavior of another element.

3.2.8 *damage or repair cost, n*—cost required to restore the building to its pre-earthquake condition, allowing for salvage and demolition.

3.2.8.1 *Discussion*—The value includes hard costs of construction as well as soft costs for design, site supervision, management, etc. (See also *replacement cost*.)

3.2.9 *damage ratio, n*—ratio of the damage or repair cost divided by the replacement cost.

3.2.10 *dangerous conditions, n*—situations that pose a threat or possible injury to the occupants or adjacent area consistent with IBC definition.

3.2.11 *deficiency, n*—conspicuous defect(s) in the building or significant deferred maintenance items of a building and its components or equipment.

3.2.11.1 *Discussion*—Conditions resulting from the lack of routine maintenance, miscellaneous repairs, operating maintenance, etc. are not considered a deficiency.

3.2.12 *demand surge, n*—a temporary economic condition following a large or great earthquake in which the increased demand for materials, labor, and services results in an increase

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from International Code Council (ICC), 500 New Jersey Ave., NW, 6th Floor, Washington, DC 20001, http://www.iccsafe.org.

[4] Available from American Society of Civil Engineers (ASCE), 1801 Alexander Bell Dr., Reston, VA 20191, http://www.asce.org.

[5] The successor of FEMA 310 issued as a standard in 2003, with periodic revisions.

[6] The successor of FEMA 356 issued as a standard in 2006, with periodic revisions.

in the cost and time to repair damage to buildings compared to the cost and time to repair the same damage under normal conditions or following smaller earthquakes.

3.2.12.1 *Discussion*—The phenomenon results from a complex time-dependent process of supply and demand. Objective and complete datasets for demand surge for large to great earthquakes in the United States are unavailable, as are peer-reviewed public models to reliably predict the effects of demand surge.

3.2.13 *design basis earthquake (DBE), n*—the site ground motion with a 10 % probability of exceedance in 50 years, equivalent to a 475-year return period for exceedance, or a 0.2105 % annual probability of occurrence.

3.2.13.1 *Discussion*—The design basis earthquake ground motions are associated with any earthquake that has the specified site ground motion value; often there are several earthquakes with different magnitudes and causative faults that yield equivalent site peak ground motions.

3.2.14 *distribution function, n*—the probability distribution for a random variable.

3.2.14.1 *Discussion*—The random variable may include such things as loss, ground motion, or other consequence of earthquake occurrence.[7,8,9]

3.2.15 *due diligence, n*—the assessment of the condition of a property for the purposes of identifying conditions or characteristics of the property, including potentially dangerous conditions, that may be important to determining the appropriateness of the property for financial or real estate transactions.

3.2.15.1 *Discussion*—The extent of due diligence exercised on behalf of a User is usually related to the User's tolerance for uncertainty, the purpose of seismic risk assessment, the resources and time available to the Provider to conduct the site visit and review construction documents.

3.2.16 *expected value, n—of a random variable*, the average or mean of the distribution function.

3.2.16.1 *Discussion*—The expected value is determined as the sum (or integral) of all the values that can occur multiplied by the probability of their occurrence. (Compare: *median value*.)

3.2.17 *fault zone, n*—area within a prescribed distance from any of the surface traces of a fault.

3.2.17.1 *Discussion*—The distance depends on the magnitude of earthquakes that could occur on the fault—typically 500 ft (152 m) from major faults, which are those capable of earthquakes with magnitudes of 6.5 or greater, and 250 ft (761 m) away from other well-defined faults. Within California, the fault zones are determined by the California Geological Survey under the Earthquake Special Studies Zones Act for active and potentially active faults that have been identified by the state or other governmental bodies.

3.2.18 *field assessor, n*—the person assigned by the Senior Assessor who conducts the site visits of the property to observe, evaluate, and document the lateral load-resisting system. Other qualified persons may assist the Field Assessor. See 6.2.3 for qualifications required to perform such functions for Level 1 or higher assessments.

3.2.19 *independent reviewer, n*—independent technically qualified individual or organization that has not been engaged in the design or modifications of the building(s), and is not in any way affiliated with the Provider.

3.2.19.1 *Discussion*—The concept may also be represented by the phrase "Independent Peer Reviewer." Independent Review is conducted during the seismic risk assessment (and typically involves interaction with the Provider) rather than after the completion of the seismic risk assessment by a Third Party Reviewer. See 6.4 and 6.5.

3.2.20 *interdependency, n*—a condition wherein the function of the building is dependent on another building, on utilities, or on other critical elements in the supply chain.

3.2.20.1 *Discussion*—Other critical elements include transportation and may include a customer, vendor (for example, supplier of materials), contractor (supplier of services), staff (for example, supplier of staff), information (for example, data processing for accounting or distribution), etc.

3.2.21 *landslide, n—(1)* ground motion, the rapid downslope movement of soil or rock material, or both, often lubricated by ground water, over a basal shear zone; and *(2)* geological, stationary material deposited in the past by the rapid downslope movement of soil or rock material, or both.

3.2.22 *lateral load-resisting system, n*—the elements of the structural system that provide support and stability to the building under seismic and wind forces.

3.2.23 *magnitude of earthquake, n*—any of a variety of measures that indicates the "size" or "energy release" of an earthquake.

3.2.23.1 *Discussion*—At least 20 different magnitude scales are in use within the technical community. The most commonly used lay term is the Richter magnitude, which is determined by taking the common logarithm (base 10) of the largest ground motion recorded during the arrival of a "P" wave, or seismic surface wave, and applying a standard correction for the distance to the epicenter of the earthquake. The measure most widely used in the technical community is the moment magnitude, a measure of the total strain energy released in the event. Magnitudes calculated using different scales can vary widely for the same earthquake.

3.2.24 *maximum capable earthquake (MCE), n*—earthquake that can occur within the region that produces the largest average ground motion at the site of interest.

3.2.24.1 *Discussion*—This is NOT the same as the ASCE 7 definition of risk-targeted maximum considered earthquake (MCE_R), or past definitions of maximum considered earthquake (MCE) as found in ASCE 7 or ASCE 41. The concept of maximum capable earthquake (MCE) for purposes of the Guide is a deterministic event, and does not include a return period value.

[7] *Earthquake Damage Evaluation Data for California*, Report ATC-13, Applied Technology Council, Redwood City, CA, 1985. ATC-13-1 issued in 2003.

[8] Thiel, C. C., and Zsutty, T. C., "Earthquake Characteristics and Damage Statistics," *Earthquake Spectra*, Earthquake Engineering Research Institute, Oakland, CA, Vol 3, No. 4, November 1987.

[9] Richter, C. F., *Elementary Seismology*, W.H. Freeman, San Francisco, CA, 1958.

3.2.25 *median value, n*—value that divides the distribution function into equal parts, such that the value of the random variable has an equal probability of being above or below the reference value. (Compare *expected value*.)

3.2.26 *Modified Mercalli Intensity (MMI), n*—qualitative description of the local effects of the earthquake at a site.

3.2.26.1 *Discussion*—Normally, MMI is given as a roman numeral, from I to XII, to emphasize its qualitative, not quantitative, nature. A single earthquake can have many different MMI intensities assigned over the region in which the earthquake is felt. Use of MMI to characterize ground motions for use in the seismic risk assessment of buildings should be done with caution because the damage level predicted is associated with a very wide range of earthquake ground motions, not a specific earthquake ground motion.

3.2.27 *non-structural components, n*—components of a building system that are not part of the vertical or lateral-load resisting structural systems nor are defined as contents.

3.2.28 *observations, n*—the relevant information or measurements, or combination thereof, documented during the site visit survey.

3.2.29 *obvious, adj*—readily accessible and can be seen easily by the Provider without the aid of any instrument or device during a site visit.

3.2.30 *occupant, n—of a building*, an individual or individuals, who is or will be occupying space in a particular building(s) under study, or a part thereof.

3.2.30.1 *Discussion*—Persons who are authorized to be present only temporarily, or in special circumstances such as those permitted to pass through during an emergency, are visitors.

3.2.31 *other earthquake hazards, n*—other earthquake hazards include, but are not limited to, soil liquefaction; ground deformation including subsidence, rupture, differential settlement, landsliding, slumping, etc; and, hazards from off-site response to the earthquake including flooding from dam or dike failure, tsunami, or seiche.

3.2.32 *owner, n*—the entity or individual holding the deed to the building, or their designated representative. An agent or contractor may be considered an owner in some circumstances.

3.2.33 *P-delta effect, n*—the secondary effect of column axial loads and lateral deflections on the shears and moments in various components of a building.

3.2.34 *peak ground acceleration, (PGA), n*—the maximum acceleration at a site caused by an earthquake ground motion. PGA may be an actual recording or an estimate. PGA is most often given as the maximum of the horizontal components and is usually expressed as a fraction of gravitational acceleration, g, 32.2 ft/s^2 (9.8 m/s^2). The terms effective peak acceleration (EPA) and/or effective maximum acceleration (EMA) are sometimes used in seismic analysis. Where EPA and EMA are used, the basis for determination and justification of use should be provided, including verification that the use requires this representation of ground motion as distinct from others.

3.2.35 *potentially active fault, n*—a fault that shows evidence of surface displacement during the Quaternary period (approximately the last two million years).

3.2.35.1 *Discussion*—This is the definition used in Earthquake Fault Zones (previously referred to as Alquist-Priolo Special Study Zones) in California. Other definitions may be appropriate in different seismic hazard regions. The point of the definition is to preclude concern for faults that have not moved in a very long time; that is, much longer time periods, such as those that dominate the Eastern and Midwestern portions of the United States.

3.2.36 *probabilistic ground motion, n*—earthquake ground motions for the building site that are determined from an evaluation of the seismic exposure for the site for a given time period and are represented by a probability distribution function. Where appropriate, the ground motion assessment process should reflect conditional probabilities of the temporal dependence of earthquakes on specific seismic features, where they are known.

3.2.37 *probable loss (PL), n*—earthquake loss to the building systems that has a specified probability of being exceeded in a given time period, or an earthquake loss that has a specified return period for exceedance.

3.2.37.1 *Discussion*—This value is meant to reflect in a statistically consistent computational manner all of the uncertainties that can impact damage, including when and where earthquakes occur and with what magnitude, attenuations of ground motion to the site, local site effects and performance of the building systems in this ground motion. The PL is expressed in terms of the damage ratio and is generally limited to earthquake loss associated with the earthquake ground-shaking hazard, but may include losses from other earthquake hazards as prescribed by a User. Dollar values can be determined by multiplying the damage ratio by the replacement cost estimate for the building. Where seismic analysis of discounted present value is to be performed then annual PL, mean and standard deviation are appropriate damageability measures for use in such application.

3.2.38 *probable maximum loss (PML), n*—term historically used to characterize building damageability in earthquakes.

3.2.38.1 *Discussion*—PML has had a number of very different explicit and implicit definitions. The concepts of probable loss (PL) and scenario loss (SL) are used in this guide to characterize the earthquake losses of an individual building or groups of buildings. When a Provider uses the term PML, it should be defined in terms of SL or PL as defined herein.

3.2.39 *provider, n*—person or organization that prepares a report and is responsible for the findings of the seismic risk assessment of a building or group of buildings.

3.2.40 *replacement cost, n*—cost required to construct an entirely new building of the same size, envelope, configuration and character as the referenced building, assuming a virgin site.

3.2.40.1 *Discussion*—Replacement cost includes costs for construction, including building materials and labor; design; site supervision; management; etc.

3.2.41 *retrofit scheme, n*—preliminary suggestion(s) of modifications or additions to the building intended to correct, mitigate, or repair a physical deficiency that will improve the seismic performance of the building so that it is acceptable to the User.

3.2.42 *return period, n—of a random variable*, is the inverse of the annual probability that the value is equaled or exceeded.

3.2.42.1 *Discussion*—Return period is not the time period between occurrences of the value, but is the long-term average of the random times between occurrences. Often, return period is incorrectly interpreted to mean that if the value was realized in 1994, and the return period is 100 years, then the next occurrence will be in 2094. For example, earthquake occurrences usually are considered as Poisson-distributed random variables, that is, variables where the probability is near constant from year to year, and the probability of an occurrence this year is independent of what happened last year. For a Poisson random variable, the probability that the value will be equaled or exceeded in its return period term is 63 %.

3.2.43 *scenario expected loss (SEL), n*—expected value of the scenario loss for the specified ground motion of the earthquake scenario selected.

3.2.44 *scenario loss (SL), n*—earthquake damage loss expectation to building systems and site improvements and where User-prescribed, contents and/or related business interruption loss, associated with specified earthquake events on specific fault(s) affecting the building.

3.2.44.1 *Discussion*—SL values are expressed in terms of the damage ratio. Dollar values can be determined by multiplying the damage ratio by the replacement cost estimate for the building. The SL is generally limited to earthquake loss associated with the earthquake ground-shaking hazard, but may include losses from other earthquake hazards, as prescribed by a User.

3.2.45 *scenario upper loss (SUL), n*—scenario loss that has a 10% percent probability of exceedance due to the specified ground motion of the scenario considered.

3.2.46 *seiche, n*—water wave caused in an enclosed, or partially enclosed, body of water in response to the passage of seismic waves.

3.2.47 *senior assessor, n*—the licensed engineer in responsible charge of the management of the assessment who affirms and attests to the report's content, findings, and conformance with referenced ASTM requirements. See 6.2.3 for qualifications required to perform such functions for Level 1 or higher assessments.

3.2.48 *significant damage, n*—damage caused that is sufficient to require guidance from a licensed engineer to determine extent of damage and necessary repairs to bring the building to a pre-earthquake condition.

3.2.49 *site visit, n*—visual reconnaissance of the site and physical property by the Field Assessor and those assisting the Field Assessor to gather information on the physical property for the purposes of preparing seismic risk assessment.

3.2.49.1 *Discussion*—The Provider is not expected to use or provide scaffolding, ladders, magnifying lenses, etc. in undertaking the visual reconnaissance of the building systems and components during the site visit. The User is expected to provide on-site ladders, if available, and to provide safe access to all parts of the structure, including the roof. This definition implies that such a visit is preliminary, not in-depth, and typically done without the aid of exploratory probing, removal of materials, or testing. It is literally the Provider's (Field Assessor's) visual survey of the building(s) and site improvements.

3.2.50 *soil liquefaction, n*—the transformation of loose, saturated, sandy soil materials into a fluid-like state.

3.2.50.1 *Discussion*—Damage from soil liquefaction results primarily from horizontal and vertical displacements of the ground. This movement of the land surface can damage buildings and buried utility lines such as gas mains, water lines and sewers, particularly at their connection to the building. Extreme tilting or settlement of the building can occur if soil liquefaction occurs underneath the building foundations.

3.2.51 *statistically consistent manner, n*—following the mathematical rules and concepts of probability and statistics.

3.2.52 *structural component, n*—component that is a part of a building's lateral and/or vertical load-resisting system.

3.2.53 *third party reviewer, n*—independent technically qualified individual or organization that has not been engaged in the design or modifications of the building(s) and is not in any way affiliated with the Provider.

3.2.53.1 *Discussion*—Third Party Review is conducted after the completion of the seismic risk assessment, rather than during the seismic risk assessment, by an Independent Reviewer. See 6.4 and 6.5.

3.2.54 *tsunami, n*—long water waves that are generated impulsively by tectonic displacements of the sea floor associated with earthquakes.

3.2.54.1 *Discussion*—Tsunamis also may be caused by eruption of a submarine volcano, submerged landslides, rock falls into the ocean, and underwater nuclear explosions.

NOTE 1—Tectonic displacements with a substantial vertical (dip-slip) component are more likely to cause tsunamis than are strike-slip displacements. Wave heights associated with tsunamis in deep water generally are small; however, as the wave fronts approach coastlines where there is shallow water, the wave heights increase and will run up onto the land. Tsunami run-up can cause loss of life and substantial property damage.

3.2.55 *uncertainty, n*—degree of random behavior represented by an applicable probability distribution and associated parameters.

3.2.56 *uncertainty tolerance level, n*—amount of uncertainty in financial exposure that a User is willing to accept resulting from the cost to remedy earthquake damage not identified by an seismic risk assessment.

3.2.56.1 *Discussion*—This can be influenced by such factors as initial acquisition cost or equity contribution, mortgage underwriting considerations, specific terms of the equity position, projected term of the hold, etc.

3.2.57 *user, n*—the party that retains the Provider to prepare a seismic risk assessment of the property in accordance with this Guide. A User may include a purchaser, potential client, owner, existing of potential mortgagee, lender or property manager of the subject property.

4. Significance and Use

4.1 *Uses*—This Guide is intended for use on a voluntary basis by parties such as lenders, loan servicers, insurers and equity investors in real estate (Users) who wish to estimate possible earthquake losses to buildings. This guide outlines procedures for conducting a seismic risk assessment for a specific User considering the User's requirements for due diligence. The specific purpose of this guide is to provide Users with seismic risk assessment during the anticipated term for holding either the mortgage or the deed. A seismic risk assessment prepared in accordance with this guide should reference or state that the guidance in this document was used as a basis for the report and should also identify any deviations from the guidelines. This guide is intended to reflect a commercially prudent and reasonable investigation for performance of seismic risk assessments.

4.1.1 *Users*—This Guide is designed to assist the User in developing information about the earthquake-related damage potential of a building, or groups of buildings.

4.1.1.1 Use of this guide may permit a User to satisfy, in part, their requirements for due diligence in assessing a building's potential for losses associated with earthquakes for real estate transactions.

4.1.2 *Types of Investigations*—This guide provides suggested approaches for the performance of five different types of assessments. Each is intended to serve different financial and management needs of the User. Several of these types of assessment specifically depend on characterization of the earthquake ground motion as given in Section 7.

4.1.2.1 *Building Stability (BS)*—Assessment of whether the building will maintain vertical load-carrying capacity in whole or in part during considered earthquake ground motions (see Section 8).

4.1.2.2 *Site Stability (SS)*—Assessment of the likelihood that the site will remain stable in earthquakes and is not subject to failure through faulting, soil liquefaction, landslide, or other site response that may threaten the building's stability or cause significant damage (see Section 9).

4.1.2.3 *Building Damageability (BD)*—Assessment of the damageability of the building(s) during earthquake ground motions and the degree of damage expected over time. The assessment includes performing and completing the building damageability assessment as either a probable loss (PL) or a scenario loss (SL) assessment, or both (see Section 10).

4.1.2.4 *Contents Damageability (CD)*—Assessment of the damageability of the contents to earthquake ground motions. This guide suggests that the contents damageability assessment be performed using the SL assessment approach (see Section 11).

4.1.2.5 *Business Interruption (BI)*—Assessment of the implications for continued use or partial use of the building for its intended purpose due to earthquake damage, whether to the building systems, or contents, or both. This guide suggests that the business interruption assessment be performed using the SL assessment approach (see Section 12).

4.1.3 *Application and Temporal Relevance of Report*—The User should only rely on a seismic risk assessment report for the specific purpose that it was intended, and upon confirmation, that the building is in the condition it was at the time of assessment and that the understanding of seismic hazards and performance of the specific building type have not changed.

4.1.4 *Availability of Information*—This guide recognizes that a Provider's opinions and observations may be affected or contingent on information (or the lack thereof) that is readily available to the Provider during the conduct of an investigation. For instance, a Provider's observations may be affected by the number of people using the building or the availability of property management to provide information, such as the construction documents.

4.1.5 *Site-Specific*—Seismic risk assessments are site-specific in that they relate to estimation of earthquake loss to building(s) located at a specific site.

4.2 *Principles*—The following principles are an integral part of this guide and should be referred to in resolving any ambiguity or exercising such discretion as is accorded the User or the Provider in estimating loss to buildings from earthquakes. The principles should also be used in judging whether a User or Provider has conducted an appropriate assessment and estimation of earthquake loss to a building.

4.2.1 *Uncertainty Not Eliminated*—No estimate can wholly eliminate uncertainty regarding damage resulting from actual earthquakes. The successive levels of investigation described in this Guide are intended to reduce, but not eliminate, uncertainty regarding the estimation of damage. This Guide acknowledges the reasonable limits of time and cost related to a selected level of assessment.

4.2.2 *Not Exhaustive*—There is a point at which the cost to gather information outweighs the usefulness of the information and, in fact, may be detrimental to the orderly completion of transactions within the resources available to support the investigation. This Guide identifies and suggests that a balance be sought between the competing goals of limiting the costs and time demands versus limiting the resulting uncertainty regarding unknown conditions or information by acquiring as much information as possible.

NOTE 2—Appropriate due diligence according to this Guide is not to be construed as technically exhaustive. There is a point at which the cost of information obtained or the time required to conduct the seismic risk assessment may outweigh the usefulness of the information and, in fact, may be a material detriment to the orderly and timely completion of a commercial real estate transaction. It is the intent of this Guide to attempt to identify a balance between limiting the costs and time demands inherent in performing a seismic risk assessment and reducing the uncertainty about unknown physical deficiencies resulting from completing additional inquiry.

4.2.3 *Level of Investigation*—Not every property warrants the same level of investigation. Consistent with good commercial or customary practice, choosing the appropriate level of investigation is guided by the type and age of buildings subject to assessment, the resources and time available, the anticipated severity of shaking, the expertise and risk tolerance of the User, and the information developed during the course of the investigation.

4.3 *Subsequent Use of Seismic Risk Assessments*—This guide recognizes that assessments of buildings prepared for specified levels of investigation and performed on the basis of the approaches discussed herein may include information that subsequent Users will want to use to avoid undertaking duplicative investigations. Consequently, this guide describes procedures to assist subsequent Users in determining how appropriate it would be to use these results. Usage of prior reports is based on the following principles that should be adhered to in addition to the specific procedures set forth in this guide.

4.3.1 *Comparability*—An estimate of loss to buildings from earthquakes is not to deemed as inappropriate merely because it did not identify all potentially vulnerable areas in connection with a building or a group of buildings. Seismic risk assessments must be evaluated based on the reasonableness of judgments made at the time and under the circumstances in which they were made. The result of any subsequent seismic risk assessments performed to similar parameters should not be considered as valid standards to judge the appropriateness of any prior seismic risk assessment based on hindsight, new information, use of developing technology or analytical techniques, or other factors.

4.3.2 *Use of Prior Information*—Users and Providers may use information in prior reports that meet or exceed the requirements of this guide for specified levels of investigation and then only provided that the specific procedures set forth in the guide were met, including the qualification of the Provider.

4.3.3 *Prior Assessment Meets or Exceeds*—A prior seismic risk assessment report prepared for specified levels of investigation may be used in its entirety, without regard to specific procedures set forth in this guide, if in the judgment of the Provider, the prior report was prepared for specified levels of investigation meeting or exceeding the requirements of this Guide and the conditions of the building(s) and the seismic hazards affecting the site are not likely to have changed materially since the prior report was prepared. In making this judgment, the Provider should consider the types of building construction assessed in the report, any new information related to the behavior of that specific building construction type in recent earthquakes, as well as current understanding of the site conditions.

4.3.4 *Current Investigation*—Prior seismic risk assessments should not be used without current investigation of conditions likely to affect the current seismic risk assessment. Likely conditions include the current level of knowledge on and experience with building constructions of particular types in recent earthquakes, as well as, current understanding of the site conditions that differ from those in existence when the prior report was prepared.

4.3.5 *Actual Knowledge Exception*—If the User or Provider has actual knowledge that the information being used from a prior seismic risk assessment report is not accurate or is suspected of being inaccurate, then such information from a prior report should not be used.

4.4 When a new seismic risk assessment is performed for the same User that is consistent with this guide and has a higher level of investigation than a prior investigation, then the new investigation should supersede the former one.

5. Assessment Methodology and Approach

5.1 *Minimum Requirements:*

5.1.1 Seismic risk assessments may be performed for an individual building or a group of buildings.

5.1.2 At the minimum, a seismic risk assessment should include an assessment of building stability (BS, Section 8) and site stability (SS, Section 9). It may also include a building damageability (BD, Section 10), contents damageability (C, Section 11), and/or business interruption (B, Section 12) assessment, or any combination of these.

5.1.3 An earthquake ground motion assessment (Section 7) should be conducted in conjunction with all seismic risk assessments.

5.1.4 The User shall select any level of investigation for these assessments (Levels 0 through 3).

5.1.5 The building damageability portion of the assessment (Section 10) may report a SL, where the specific scenario and the statistical measure reported or the probability of exceedance are given, or a PL with specified probability of exceedance and time period, or both.

5.1.6 The contents damageability (Section 11) and business interruption (Section 12) portions of the assessment should be reported on the basis of a scenario loss approach.

5.1.7 *Retrofit*—In some cases, information on retrofitting the building may be requested by the User under specified conditions, typically instability or damage exceeding a threshold value. In such cases, recommendations should be developed for modifications of the building's structural or nonstructural systems, or both, including members and connections, aimed at the assessed conditions. The required assessment should be performed for both the building in its existing condition and for the retrofitted building condition(s), assuming the retrofit is completed as recommended with good professional practice.

5.1.8 The use of any interactive computer assessment tools developed specifically to assess the earthquake loss and requiring only general information about the building and site (for example, structure type) should be limited to Level 0 (screening level) assessments.

5.2 *Level of Investigation:*

5.2.1 Seismic risk assessments may consider varying degrees of assessment of a building or buildings from Level 0 to Level 3.

5.2.2 Four levels of investigation are described (Level 0 through Level 3), except for the assessment of ground motion for which there are three levels (Level 0 through Level 2).

5.2.3 Level 0 is a screening investigation, while Level 3 is a highly detailed technical investigation. Levels 1 and 2 are intermediate between these two.

5.2.4 The selection of the level of the investigations performed should be guided by the expected level of uncertainty in the result that is acceptable to the User. The lower the tolerance for uncertainty, the higher the Level of investigation should be. The higher the seismic hazard of the region in which the building(s) is located, the higher the level of assessment should be, all other things being equal.

5.3 *Seismic Risk Assessment for Multiple Buildings:*

5.3.1 Where projects consist of multiple buildings or building structural units (sections) where earthquake impacts are independent of each other, one or more of the following should be presented in the building loss assessment:

5.3.1.1 Building loss results for each individual building or building sections, in addition to those of the group. These results may be expressed as an expected, mean, range, or statistic, for example, a value with 10 % probability of exceedance;

5.3.1.2 Mean and standard deviation of loss for each building or building section for selected specific events, or for the ground motion probability distribution at the site(s);

5.3.1.3 SL or PL values for a group of buildings must be determined using a statistically valid approach, including weighting of the contribution statistics by the relative replacement values for each element of the group.

5.3.1.4 Aggregate PL's and SL's for a group of buildings must be determined in a manner that is consistent with the assumptions of the damage statistics model used. If the individual buildings are co-located and are subject to earthquake ground motions of the same intensity (consistent with the statistical distribution of the damage model), then conventional statistical sampling methods can be applied to determine aggregate damage statistics. If they are not, which will be typical for geographically dispersed groups, then more detailed models that reflect the sources of uncertainty for sources and sites must be used for each building.

5.4 *Retrofit Scheme Development:*

5.4.1 In some instances, the User may specify that the assessment be related to a retrofit scheme for the building. In such cases, the retrofit scheme should be described with sufficient detail that the projected earthquake losses of the retrofitted building can be reasonably estimated.

5.4.2 The principle building characteristics, the nature of any deficiencies, and the approach to their mitigation should be identified and described in sufficient detail, such that an Independent Reviewer can adequately understand the basis for the suggested work and evaluate its efficacy.

5.4.3 The description of the retrofit scheme is not intended to be a design, and should not be used as such; it should be considered simply as a discussion of the approach to the retrofitting that may guide a designer to identify the basic earthquake performance issues of the building that require mitigation or verification of their expected performance.

5.4.4 Use of procedures and recommendations of ASCE 41 are suggested. They provide technical guidance for the seismic evaluation and retrofit of existing buildings.

6. Individuals Involved and Their Responsibilities

6.1 *General:*

6.1.1 The estimation of earthquake loss to a building(s) may be conducted by either a qualified agent or employee of the User or wholly by a Provider.

6.1.2 The User should retain only those who have the requisite knowledge and experience to perform seismic risk assessment studies in a reliable manner for the level of investigation specified.

6.1.3 There are three main qualifications that bear on the ability of the Provider to reliably give professional opinions on the earthquake hazard posed by a site and the losses to a building:

6.1.3.1 Knowledge of the current state of understanding and application of the underlying professional and scientific disciplines that bear on the particular practice; and

6.1.3.2 Experience in application of the specific professional skills required for seismic evaluation of the specific buildings and conditions of the subject site or building.

6.1.3.3 All Providers of Level 1 and higher inquiries should have a working knowledge of ASCE 41 and ASCE 7.

6.1.4 *User's Responsibilities:*

6.1.4.1 *User Requirements*—Specific technical requirements for the study including the level of each assessment, if any, including ground motion, site stability, building stability, building damageability, building content, and/or interruption, that shall be prepared.

6.1.4.2 *Access to Property and Records*—The User should arrange for or provide the Provider with timely access to all reports, drawings, and specifications for the building(s), both for the original building and for any modifications, alterations or additions. This should include all geotechnical reports and analyses of the site and any reports of engineering investigation of the building, particularly those following earthquakes. Where not on hand, these records often can be obtained from the governing jurisdiction or they can be obtained from the responsible design professional.

6.1.4.3 *Access to Consultants*—The User should provide, to the extent practicable, timely access to consultants who have designed the building or supported its design, analysis, and assessment.

6.1.4.4 *Investigation Level*—The User should establish the level(s) of investigation on building stability (BS), site stability (SS), building damageability (BD), contents damageability (C), and business interruption (B) that is commensurate with the risk tolerance level of the User.

6.1.4.5 *Return Period*—The User should establish the return period(s) for seismic activity to be used in the seismic risk assessment.

6.2 *Provider Minimum Qualifications:*

6.2.1 The following general guidance is given on setting of acceptable qualifications of Providers to perform seismic risk assessment(s). This guidance is not intended to override any state or local statutes governing licensing requirements applicable to the performance of any of the assessments included in seismic risk assessment(s). It should be noted that the qualifications for conducting building stability and building damageability assessments are similar, but different from those for ground motion, site stability, contents damageability, and business interruption. It is seldom that one individual will have sufficient expertise and experience to perform all of these types of investigations for Level 2 or Level 3 investigations. Note that many state licensing laws require engineering opinions on these issues to be performed by licensed professionals.

6.2.2 *Level 0 Investigations:*

6.2.2.1 There are no specific professional qualification requirements for Level 0 investigations; however, it is suggested that the individual performing the assessment be a registered professional and that their degree of competence in the related area of the assessment be declared.

6.2.3 *Level 1, 2, and 3 Investigations:*

6.2.3.1 The Senior Assessor shall retain overall responsibility for the seismic risk assessment. The task of visiting the subject property for visual assessment may be delegated to the Field Assessor, should the Senior Assessor believe such a separation of tasks is justified.

6.2.3.2 The Senior Assessor responsible for the overall assessment must be an engineer licensed to practice civil or structural engineering with at least the following levels of experience, measured concurrently:

(1) Ten years of general structural engineering of buildings,

(2) Five years of seismic design and analysis experience of buildings, and

(3) Three years of seismic risk assessment of buildings.

6.2.3.3 The Field Assessor responsible for visual assessment must be an engineer licensed to practice civil or structural engineering with at least the following levels of experience, measured concurrently:

(1) Five years of general structural engineering of buildings,

(2) Three years of seismic design and analysis experience of buildings, and

(3) Two years of seismic risk assessment of buildings.

6.2.3.4 When relevant structural drawings are available for review by the Senior Assessor, or the building was constructed during or after the ASCE 41 benchmark year and no significant structural modifications have occurred, the Senior Assessor may designate a Field Assessor with a lesser degree of qualifications. As an example, the Field Assessor should be at least a licensed professional architect, structural or civil engineer with a minimum of five years of experience in building design or evaluation. The Senior Assessor shall be responsible for determining the acceptable degree of qualifications for the specific investigation.

6.2.3.5 While it is not required that the Field Assessor be employed by the same organization as the Senior Assessor, it is strongly recommended due to the importance of close communication between these individuals as well as the responsibility of the Senior Assessor to assure proper qualifications of the entire assessment team.

6.2.3.6 The Senior Assessor shall have specific experience in the characteristics of the particular-structural system would be useful.

6.3 *Evaluation of Personal Qualifications and Experience of Providers:*

6.3.1 The User shall evaluate the qualifications of a Provider prior to their retention. The following issues are ones for which the User should verify information on the Provider's qualifications and experience:

6.3.1.1 *Personnel*—Identification of the Senior Assessor and Field Assessor to be engaged in the specific seismic risk assessment. Resumes should be provided that illustrate the assigned personnel have sufficient experience and knowledge of the technical, analytical, and mathematical concepts required for the performance of the level of investigation undertaken by the specified individuals.

6.3.1.2 *Professional Registrations or Licensing*—The state, type, and dates of professional registration or licensing of the Senior Assessor and Field Assessor, with an inclusion of a statement of whether the registration process specifically included earthquake issues.

6.3.1.3 *Design and Retrofit Experience*—The number of years of experience in earthquake-related design and retrofit practice of the Senior Assessor and Field Assessor, with an enumeration of projects and the roles played in these projects, and experience with construction type for the current assignment.

6.3.1.4 *Research and Professional Practice Development Experience*—Research and professional practice development related to earthquake hazards that bears on the specific professional duties that are to be performed.

6.3.1.5 *Seismic Risk Assessment Experience*—The number of years of experience in seismic risk assessment of the Senior Assessor and Field Assessor with an enumeration of projects and the roles played in those projects that are comparable to the type of conditions that are expected to be encountered.

6.3.1.6 *Earthquake Investigation Experience*—A listing of the earthquakes investigated, including the citations of reports, assessments or repairs that the Senior Assessor and Field Assessor prepared or to which they made contributions.

6.4 *Independent Review:*

6.4.1 *General:*

6.4.1.1 Independent review is intended to be an objective technical review by a knowledgeable reviewer(s) experienced in the structural design, analysis, and seismic performance issues associated with the specific building(s).

6.4.1.2 The User may wish to use independent peer review of the seismic risk assessment(s) as a means of improving confidence and reducing the level of uncertainty in the reported results.

6.4.2 *Qualifications and Terms of Employment:*

6.4.2.1 The Independent Reviewer should be independent from the Provider.

6.4.2.2 The Independent Reviewer should have technical expertise meeting or exceeding the requirements specified for the Senior Assessor.

6.4.2.3 The Independent Reviewer should have a declared competence in earthquake loss estimation, seismic hazard evaluation, and probability and statistics as deemed appropriate for the level of the investigation.

6.4.3 *Selection of Independent Reviewer:*

6.4.3.1 The Independent Reviewer(s) may be selected at any point during the seismic risk assessment process, but should be selected prior to its completion.

6.4.4 *Independence:*

6.4.4.1 The Independent Reviewer should have no other involvement in the earthquake loss estimation process, for the specific building before, during, or after the review, except in the review capacity.

6.4.5 *Independent Review Report:*

6.4.5.1 The Independent Reviewer should prepare a written letter report to the User.

6.4.5.2 The Independent Reviewer's report should cover all aspects of the review performed; including conclusions reached by the reviewer, and identify any areas, which need improvement or further study, investigation, or clarification.

6.5 *Third Party Review:*

6.5.1 Third Party Review is intended to be an objective technical review of an existing seismic risk assessment by a knowledgeable reviewer(s) experienced in the structural design, analysis, and seismic performance issues associated with the specific building(s).

6.5.2 When a third party technical review is required by the User, the Third Party Reviewer should have technical qualifications that are equal to or greater than those of the Senior Assessor (or most qualified person who worked on the report being assessed for reports pre-dating requirements for Senior Assessor).

6.5.3 The Third Party Reviewer shall disclose any and all relationships, past and present, with the Provider, and prior work or evaluations of the buildings reviewed that could influence the Third Party Reviewer's opinions and findings.

7. Seismic Ground Motion Hazard Assessment

7.1 *Objective*—The objective of the seismic ground motion hazard assessment is to characterize the earthquake ground motions at the site(s) with a specified probability of being exceeded in a given time period and/or scenario earthquake ground motions associated with specific source events that are likely to impact the site(s).

7.1.1 The ground motion level of investigation should always be at least as high as the level of the investigation its results are used in, except that Level 3 investigations may use a Level 2 ground motion investigation.

7.1.2 All faults and features for which there is reasonable professional basis or consensus within the engineering, seismology and geology disciplines to assign a maximum capable earthquake to the fault or feature should be assessed.

7.1.3 The ground motion at the site should be determined by application of an appropriate attenuation relationship determined from those available that best represent the specific seismic and tectonic setting of the immediate region and recognize the local underlying site class in Level G1 and G2 investigations.

7.1.4 The significance of other earthquake hazards such as soil liquefaction, ground deformation and flooding from dam or dike failure, tsunami, or seiches should be evaluated for earthquakes whose ground motions are comparable to the level prescribed in developing seismic loadings for the site by the current edition of the International Building Code or other nationally applicable building code for the site class and building types.

7.1.5 The ground motion assessment process may reflect conditional probabilities of the temporal dependence of earthquakes on specific seismic features where they are known.

7.2 *Levels of Investigation in Seismic Ground Motion Hazard Assessment:*

7.2.1 There are three levels of investigation in ground motion hazard assessment. They are described as Level G0, Level G1, and Level G2. Level G3 is not used. The ground motion representation, whether PGA, other engineering measures of acceleration, spectral ordinates, or time histories, must be consistent with the analysis procedures that use them.

7.2.2 *Level G0 Investigation (Screening Level)*—This level should consist of, but not be limited to:

7.2.2.1 Ground motion values determined from the USGS website or commercial software based on specific locations (for example, latitude/longitude, or street address).

7.2.3 *Level G1 Investigation*—This investigation should consist of, but not be limited to, ground motion values for the site determined from commercially available software or USGS web-based tools based on the provision of project coordinates (latitude and longitude) and site class, provided the software provides probabilistic estimates of ground motion that consider all sources of earthquakes and includes uncertainty in ground motion attenuation relationships.

7.2.4 *Level G2 Investigation*—This investigation should consist of, but not be limited to, the ground motion values for the site developed as a specific project site Probabilistic Seismic Hazard Analysis (PSHA)[10] that includes response of the soil column.

7.2.4.1 The PSHA provides a framework to identify and characterize the nature of earthquake sources, the seismicity or temporal distribution of earthquakes on those sources, the ground motion produced by those sources, and the uncertainties associated with each, when combined, to obtain the value of ground motion parameters that have a given probability of being exceeded during a particular time period.

7.2.4.2 *Identification of Hazard Sources*—Hazard sources should include all possible sources of seismic activity that may affect the building site. Identification of those sources may be conducted by the methods indicated in 7.2.4.3 through 7.2.4.9. If reports, or other reference publications, or both, are used, it should be verified that these methods were used.

7.2.4.3 *Geologic Evidence (Paleoseismology)*—Geologic records may contain evidence of the occurrence of earthquakes, primarily in the form of offsets, or relative displacements, of various strata. Such offsets may indicate the presence of faults. Tools and techniques to be used may include the review of published literature; interpretation of aerial photographs; remote sensing (infrared photography) imagery; field reconnaissance, including logging of trenches, test pits and borings, and geophysical techniques.

7.2.4.4 *Tectonic Evidence*—Earthquakes occur at tectonic plate boundaries to relieve the strain energy that accumulates as the plates move relative to one another. Geologic indicators may indicate the rate of strain energy accumulation from tilting and changes in distances between fixed points on the ground.

7.2.4.5 *Historical Seismicity*—Earthquake sources may be identified from records of historical or pre-instrumental seismicity. Historical accounts of associated ground shaking may be used to confirm the occurrence of past earthquakes and aid in the identification of seismic sources.

[10] McGuire, R., *Seismic Hazard and Risk Analysis*, Earthquake Engineering Research Institute, Oakland, CA, Monograph MNO-10, 2004.

7.2.4.6 *Instrumental Seismicity*—Instrumental records of earthquakes and aftershocks may be used to identify earthquake sources and aid in delineating the orientation and geometry of the source.

7.2.4.7 *Recurrence of Events*—The activity of the seismic sources should be established to estimate the recurrence of earthquake events on those sources. Fault activity may be evaluated based on geologic (paleoseismic) evidence, instrumental evidence, or inferences from geologic data. Estimates of the size of past earthquakes may be made from correlations of observed information characteristics with known magnitudes. The activity and size information may be used to estimate the recurrence of events.

7.2.4.8 *Attenuation Relationships*—The approach and method used should be fully described. Predictive relationships should account for variables that are significant in estimating ground motion parameters. These variables may include earthquake magnitude, distance from source to site, wave propagation path, terrain effects, topographic features, underlying soil profile, type of faulting, directivity effects, and orientation of the component of the ground motion parameter.

7.2.4.9 *Accuracy and Completeness*—The PSHA should account for those uncertainties that can be identified and quantified (either by a range of possible values or by a probability density function) and should be incorporated in a rational manner to evaluate the seismic hazard. Sources of uncertainty include uncertainty in spectral parameters due to source characteristics, uncertainty in the size of earthquakes, uncertainties in the earthquake recurrence relationship, uncertainty in the ground motion parameter attenuation relationship, and temporal uncertainty due to creep data. Where more than one seismic hazard model is plausible, a logic tree representation may be used that weighs the various models; this usually is reserved for use in high level investigations. When a hazard value, such as 10 % in 50 years, is assigned for a ground motion parameter, it should be stated that the hazard value is based on a joint probability evaluation of the uncertainties such as a weighted logic tree representation, or based on assigned discrete values of the uncertainties such that the hazard value is conditional on these discrete values. Also representations such as mean value or mean value plus one standard deviation should be stated. For example, PGA values may be found in terms of the attenuated mean of the natural logarithm of PGA, having a known standard deviation (sigma) of prediction error.

8. Building Stability Assessment

8.1 *Objective*—The objective of the building stability assessment is to determine if the building can be reasonably expected to remain stable under earthquake loadings. A building should be deemed stable if it is able to maintain the vertical load carrying-capacity of its structural system under the inelastic deformations caused by the earthquake ground motion prescribed for the building and site by the current edition of the International Building Code or other nationally applicable building code as specified by the User.

8.1.1 A group of buildings should be deemed stable if each of the buildings in the group is deemed stable.

8.2 *Levels of Investigation in Building Stability Assessment*—There are four levels of investigation in Building Stability Assessment. They are described as Level BS0, Level BS1, Level BS2, and Level BS3. The level of the building stability assessment should be the same as that used for the building damageability assessment, if such is assessed.

8.3 *Conclusions and Findings*—These findings should be commensurate with the level of investigation being performed on the building. Observations and any analysis performed may be completed in conjunction with the building damageability assessment, if performed. The results of the assessment must state if an unstable condition exists or not, and under what conditions.

8.4 *Level BS0 Investigation (Screening Level)*—This investigation should consist of, but not be limited to, the following:

8.4.1 Determination of the gravity and lateral load-resisting systems for the building by review of the construction documents or visual observation of the building, if no documents are available. Where construction documents are not available for review, the era in which the building was designed should be estimated, as well as the governing building code used at the time of construction.

8.4.2 Evaluate the stability of the building under gravity and earthquake loads based on the building type and era of construction using general information such as benchmark years in ASCE 41.

NOTE 3—Many situations currently known to be potentially hazardous may have been considered acceptable under the building code to which the building was originally designed and constructed, but are no longer deemed acceptable.

8.4.3 Special consideration should be given to any irregular conditions that may create instabilities such as weak stories, columns restrained by sloping floors or stiff wall panels, long unbraced elements, and potentially fragile materials and systems such as unreinforced masonry, precast concrete elements, etc., that may pose obvious falling hazards.

8.4.4 A BS0 level of investigation has an inherently high uncertainty in result.

8.5 *Level BS1 Investigation*—This investigation should consist of, but not be limited to, the following:

8.5.1 A site visit of the building by a Senior or Field Assessor as stated in 6.2.3.4 to determine its condition and quality of construction, including significant modifications since original construction.

NOTE 4—To reasonably establish conditions, the framing elements should be readily accessible and be easily observed and understood by the Provider without the aid of any instrument or devices as a result of a site visit.

8.5.1.1 A limited review of construction documents, or the acquisition of sufficient information via onsite investigations such that an analogous level of relevant information is obtained.

8.5.2 Identification of the gravity and lateral load-resisting systems for the building.

8.5.3 Determination of whether conditions exist that are known to lead to instability in whole or part of the building when subject the earthquake loadings specified in 8.1, such as long unbraced elements or discontinuous shear walls. Instability, in part, includes those circumstances when a portion of a building fails, but many portions of the building remain stable, although they may be damaged. An example is a canopy at the entrance of a building or a parapet. The analysis procedure shall be determined by the Provider responsible for the project and shall be stated in the report. As a minimum, the level of evaluation of the structural systems for Building Stability BS1 shall be a level of effort consistent with an ASCE 41 Tier 1 structural evaluation, or comparison to other standards such as building codes with similar level of evaluation for critical components.

8.5.3.1 Simply noting the building code in which the building was originally designed to does not satisfy the BS1 requirement.

8.5.3.2 Particular attention should be given to the configuration, compatibility, continuity, redundancy, condition of structural elements, and whether there are unusual loads applied to the building.

8.5.4 Where possible, sufficient examples of the structural framing should be visually observed to reasonably establish the obvious condition and characteristics of both the gravity and lateral load-resisting systems.

NOTE 5—To reasonably establish conditions, the framing elements should be readily accessible and be easily observed and understood by the provider without the aid of any instrument or devices as a result of a site visit.

8.5.5 The added knowledge of the building provided by a Level BS1 investigation can increase the level of confidence of the Provider above that of a BS0 investigation, although there will still be a relatively low degree of confidence without the ability to analytically verify the competence of the structural design. If drawings are not available for review, then the level of confidence is reduced to that of a Level 0 investigation with enhanced other characteristics consistent with the investigation, but always a higher uncertainty level than for a Level 1 assessment.

8.6 *Level BS2 Investigation*—In addition to the requirements described in a Level BS1 investigation, a Level BS2 investigation should consist of, but not be limited to, the following:

8.6.1 Detailed review and assessment of the existing construction documents for the building or, if they are not available, measured drawings and results of destructive or nondestructive testing characterizing the structural system, including both original construction and any modifications that may have subsequently occurred.

8.6.2 Engineering calculations as required to determine the anticipated structural behavior of elements or systems. The evaluation should include stability issues such as weak column-strong beam conditions in rigid frames, bracing members and their connections, and the ability of gravity load-bearing members (structural and nonstructural) that are not part of the lateral load-resisting system to tolerate the effects of the expected inter-story drifts. Site improvements that could impact stability of building should be identified.

8.6.3 Nondestructive testing of building elements may be performed to generally establish the type, construction, capacity, and condition of materials.

8.6.4 The added knowledge of the building provided by a Level BS2 investigation can increase the level of confidence of the Provider above that of a BS1 investigation to a level that is relatively low. However, if drawings are not available for review, the increase in level of confidence is reduced.

8.6.5 The analysis procedure shall be determined by the Provider responsible for the project and shall be stated in the report. As a minimum, the level of evaluation of the structural systems for Building Stability BS2 shall be a level of effort consistent with the ASCE 41 Tier 1 structural evaluation with a Tier 2 deficiency-based review conducted on all Non-Compliant items. Alternatively, the building may be evaluated to other standards such as adopted building codes with a similar level of evaluation for critical components.

NOTE 6—Evaluation using building codes is only appropriate with buildings that are relatively new and have code compliant or nearly code compliant detailing. Use of code procedures for buildings constructed prior to benchmark years in ASCE 41 is not encouraged.

8.7 *Level BS3 Investigation*—In addition to the requirements described in a Level BS2 investigation, a Level BS3 investigation should consist of, but not be limited to, the following:

8.7.1 If drawings are not available or complete, then comprehensive destructive and nondestructive testing meeting the testing requirements of ASCE 41-13 shall be performed.

8.7.2 Perform at least a two-dimensional numerical analysis (a three-dimensional analysis may be more beneficial) of the lateral load-resisting system of the building, including all P-delta and torsional effects. Where site-specific or nearby ground motion records exist and are available, these should also be used in evaluating past building seismic performance.

8.7.2.1 From this analysis, the stability issues for both structural and nonstructural elements and systems can be more quantitatively evaluated, especially those dealing with the drift effects on non-frame elements. Any nonstructural components that, in the opinion of the Provider, may cause instability of the building should be considered in the analysis and their impacts on the stability of the building evaluated.

8.7.3 For buildings exhibiting highly irregular structural systems or where the consequence of failure is significant, include the effects of a site specific response spectrum or time histories appropriate for the site and proximity to faults.

8.7.4 The User should consider implementing the independent review process to ensure acceptable technical performance.

8.7.5 Based on the nature of the building, a progressive failure (push-over) analysis may be performed.

8.7.6 The Level BS3 investigation increases the level of confidence to a level the highest that can be achieved. Even with comprehensive destructive and nondestructive testing in accordance with ASCE 41, the lack of drawings reduces the level of confidence that might otherwise be attained.

9. Site Stability Assessment

9.1 *Objective*—The objective of the site stability assessment is to determine if the building is located on a site that may be subjected to instability due to earthquake hazards. The following should be determined:

9.1.1 *Active Fault Zone*—If the building is located within a fault zone determined as a generally recognized active fault as identified by any federal, state, or local governmental agency, or other authoritative source.

9.1.2 *Potentially Active Fault Zone*—If the building is located within a fault zone determined as a generally recognized potentially active fault as identified by any federal, state, or local governmental agency, or other authoritative source.

9.1.3 *Other Significant Earthquake Hazards*—If the building is located such that its exposure to other earthquake hazards is deemed significant, including, but not limited to, soil liquefaction, landslide, ground deformation, flooding from dam or dike failure, tsunami, or seiche. The significance of such hazards is to be evaluated assuming the occurrence of earthquakes whose ground motions are comparable to those required by the applicable building code or national standard; other User-prescribed seismic event such as the design basis earthquake (DBE) may be used.

9.2 *Levels of Investigation in Site Stability Assessment*—There are four levels of investigation in site stability assessment of real estate. They are described as Level SS0, Level SS1, Level SS2, and Level SS3.

9.3 *Level SS0 Investigation (Screening Level)*—A level SS0 investigation should consist of, but not be limited, to the following:

9.3.1 Determination of site characteristics from generally available published reports and maps coded to general areas of susceptibility such as maps identifying general areas of seismic hazard susceptibility, perhaps established by postal zip codes, Alquist-Priolo Zones in California, geographic location, or other defined system.

9.3.2 Determination of whether the area where the site is located has fault rupture, soil liquefaction, subsidence, settlement, or landslide susceptibility from generally available studies or from a geotechnical report for the site.

9.3.3 Determination of whether the site is susceptible to tsunami inundation or if site is located near an enclosed body of water and susceptibility to earthquake caused seiche, or located near a dam, the rupture of which could cause water waves impacting the property.

9.3.4 An SS0 level investigation has an inherently high uncertainty in result.

9.4 *Level SS1 Investigation*—A Level SS1 investigation should consist of, but not be limited to, the following:

9.4.1 Determination of site conditions for the building location from generally available published reports and maps.

9.4.2 Review of the geotechnical report, if available, for site-specific information. If site-specific information is unavailable, then geotechnical reports for adjacent or nearby sites can be used to quantify the building site condition, if geological conditions of the sites are believed similar.

9.4.3 Further determination of whether the site is located within a zone where there is susceptibility to faulting, soil liquefaction, lateral spreading, landslide, or other earthquake site-failure hazards.

9.4.4 Determination of whether the site is located near an unstable landmass subject to landsliding that could affect the building site.

9.4.5 Determination if site is located near ocean shoreline for susceptibility to tsunami or if site is located near an enclosed body of water for susceptibility to seiche, or dam rupture caused water waves, or both.

9.4.6 The added knowledge of the building provided by a Level SS1 investigation can increase the level of confidence of the Provider above that of a SS0 investigation, although there will still be a relatively low degree of confidence. If a geotechnical report for this or adjacent site is not available, the increase in level of confidence is reduced.

9.5 *Level SS2 Investigation*—In addition to the requirements described in a Level SS1 investigation, a Level SS2 investigation should consist of, but not be limited to, the following:

9.5.1 Review of the geotechnical report and site-specific assessment of the site stability potential based on existing information relative to the site. In addition, if not performed as part of original site-specific geotechnical investigation, perform an assessment of the degree of site stability expected and its implications for damage to the building. If no geotechnical report is available, then site-specific investigations to determine site soil conditions are required.

9.5.2 If possible site instability is expected, determine if the building is at risk of significant damage due to the expected site failure. Such failure is to be evaluated at the earthquake ground motions specified in 8.1.

9.5.3 The added knowledge of the site hazard provided by a Level SS2 investigation can increase the level of confidence of the Provider above that of a SS1 investigation to a level that is moderate.

9.6 *Level SS3 Investigation*—In addition to the requirements described in a level SS2 investigation, a Level SS3 investigation should consist of, but not be limited to, the following:

9.6.1 Performance of a site-specific response assessment (if not performed as part of original site-specific geotechnical investigation), possibly including field explorations (trenching, borings, cone penetrometer studies, etc.), modeling of the site response, and modifications of soil response due to interaction with the building foundation system and the supporting soils.

9.6.2 The User should consider implementing the independent review process to ensure acceptable technical performance.

9.6.3 The Level SS3 investigation increases the level of confidence to a level the highest that can be achieved without extensive site investigation.

10. Building Damageability Assessment

10.1 *Objective*—The objective of the building damageability assessment is to characterize expected earthquake losses associated with earthquake ground shaking and possible other earthquake hazards as prescribed by a User by performing an assessment of the damageability characteristics of the building(s) at given levels of earthquake ground motions. Earthquake loss estimates shall reflect the level of uncertainty in the Building Damageability Assessment as affected by the site hazard characterization, construction documents reviewed, site visit, and engineering investigation conducted.

10.1.1 The building damageability analysis includes all elements of the building system.

10.1.2 Building damageability may be expressed as the scenario loss (SL) or the probable loss (PL). The results may be reported as either the mean of the value or the value with a given upper confidence, or a combination thereof.

10.1.2.1 *Scenario Loss Approach:*

(1) The ground motion used for determination of the SL can be specified in a variety of ways, including:

(a) Ground motion in the MCE for the building site.

(b) Ground motion specified as the design ground motion in the applicable building code for the building site.

(c) Ground motion from specific earthquake(s) likely to affect the building site with a specified probability of exceedance, using an accepted attenuation relationship for the seismic setting and with the uncertainty of the estimate clearly indicated.

Note—Such scenario events may be prescribed for various faults based on paleoseismic evidence, and may include the MCE.

(d) Ground motion with a specified return period as determined from a probabilistic ground motion seismic hazard analysis.

(2) SL values for groups of buildings should be determined in a statistically consistent manner that fully recognizes the probabilistic damage distribution functions for the individual buildings and the possible correlations between the buildings' damageabilities.

(3) SL values may be given as:

(a) SEL (scenario expected loss) values,

(b) SUL (scenario upper loss) values,

(c) Mean with standard deviation,

(d) Probability distribution functions, and/or

(e) Values with a stated probability of exceedance.

(4) Where the buildings in a group are located at nearby sites with common site soil conditions and expected earthquake ground motions, the earthquake ground motions for each building's damageability determination may be correlated fully such that the building damageability distributions are based on the same ground motions.

(5) Where the sites are geographically-dispersed, or the building site soil conditions are different, then the building damageability determinations should consider the degree of correlation in ground motions for the separate site conditions as part of the SL determination.

10.1.2.2 *Probable Loss Approach:*

(1) The PL estimates should be evaluated, in a statistically consistent manner, considering the probabilistic distribution of ground motion at the site from all possible earthquakes that can impact the site and the probabilistic damage distribution function for the building's damageability due to each possible level of earthquake ground motion. Where several buildings are assessed, the PL values for a group of buildings should be determined in a statistically consistent manner that fully recognizes the probabilistic damage distribution functions for the individual buildings and the possible correlations between the buildings' damageability.

(2) The dynamic response characteristics of the building(s) and their influence on building damageability and seismic performance should be recognized and considered in the analyses.

(3) Building damageability distribution can be determined from past performance data, expert estimates of performance, detailed analysis at specific ground motion levels, or a combination thereof.

(4) PL values are given either as a value(s) with a specified return period(s), PLN, or as the value that has specified probability of exceedance (from 1 to 50 %) in a given time period (1 to 50 years).

(5) The most common return periods used are 72, 190 and 475 years, that correspond to a 50 % probability of exceedance in 50 years, and a 10 % probability of exceedance in 20 and 50 years, respectively.

(6) Where the buildings in a group are located at nearby sites with common expected earthquake ground motions, the earthquake ground motions for each building's damageability determination may be fully correlated such that the building damageability distributions for the individual buildings are based on the same ground motions.

(7) Where the sites are geographically-dispersed, or the building site soil conditions are different, then the building damageability determinations should consider the degree of correlation in ground motions for the separate site conditions as part of the PL determination.

10.2 *Levels of Investigation in Building Damageability Assessment*—There are four levels of investigation in building damageability assessment. They are described as Level BD0, Level BD1, Level BD2, and Level BD3.

10.3 Each building damageability analysis should consider all earthquakes that can potentially impact the site that are expected to have magnitudes greater than 5.0, and PGA values greater than 0.05 g at the site, except where other values are specifically justified by characteristics of the specific building(s) and geological conditions.

10.4 *Level BD0 Investigation (Screening Level)*—A Level BD0 investigation should consist of, but not be limited to, the following:

10.4.1 Determination of the general architectural and structural characteristics of the building and its seismic force-resisting systems.

10.4.2 Evaluation of the building's damageability by determining the building code seismic provisions to which it was designed, the type of lateral load-resisting system, condition of the building's structural elements, age of the building, and its gross characteristics, including, but not limited to, configuration, continuity of load paths, and presence of weak story or short columns.

10.4.3 Determination of the SL or PL values from tables or an equivalent procedure for a generic basic building type representative of the building: possibly completed with the aid of an interactive computer program.

10.4.3.1 Adjustments should be made to accommodate deviations of the specific building's characteristics from that of the standard or tabulated building types.

10.4.4 The impacts on building damageability from possible site instability are not included in a BD0 assessment.

10.4.5 A BD0 level investigation has an inherently high uncertainty in result.

10.5 *Level BD1 Investigation*—A BD1 investigation should consist of, but not be limited to, the following:

10.5.1 Site visit to the building by Senior or Field Assessor to determine condition, structural characteristics, and quality of construction of representative components.

10.5.2 Review the construction documents, if available.

10.5.3 Evaluation of the seismic loads and capacities of selected systems and elements and connections. The level of effort should be consistent with level of effort for ASCE 41-13 Tier 1 evaluation.

10.5.4 Identification of potential flaws in the lateral load-resisting system systems that contribute to the building's damageability without performing a detailed investigation. Particular attention should be given to configuration, compatibility, continuity, redundancy, condition of structural elements, and whether there are unusual loads applied. Identification of nonstructural conditions that may contribute to the damageability of the building.

10.5.5 Estimation of ground motion characteristics by a Level G1 or higher investigation.

10.5.6 Determination of the SL or PL values from tables or equivalent procedures for a basic building type; possibly completed with the aid of an interactive computer program, but not solely on such a basis. The reasoning for acceptance or adjustments to values determined in this manner must be documented.

10.5.7 The impacts of possible site failures need not be included in the assessment.

10.5.8 A Level BD1 investigation has an inherent moderate uncertainty in its result. If drawings are not available, the reduction in the level of uncertainty compared to BD0 investigation with drawings is reduced.

10.6 *Level BD2 Investigation*—In addition to the work described in a Level BD1 investigation, a Level BD2 investigation should consist of, but not be limited to, the following:

10.6.1 Detailed site visit by Senior or Field Assessor to observe conditions, structural characteristics, and quality of construction throughout the building.

10.6.2 Evaluation of the condition of the building and its components, and quality of construction, including significant modification since original construction.

10.6.3 Detailed examination of the building construction documents, or conditions deduced from observation if the documents are not available, and perform selected structural calculations to verify demand/capacity ratios of the building's critical structural elements expected seismic response.

10.6.4 Engineering calculations as required to determine the anticipated structural behavior of elements or systems. Determination of the seismic response characteristics of the building by assessing those issues likely to dominate its performance, including, but not limited to, deformation characteristics, redundancy of load paths, strength of elements and systems, toughness of elements and connections.

10.6.5 Estimation of the damage to all building systems and site improvements that can affect the building based on a Level G2 or higher assessment, and compute the PL or SL values reflecting these ground motion distributions.

10.6.5.1 PL or SL values shall not be determined solely from tables, equations, or equivalent procedures for a generic basic building type, nor from use of interactive computer programs that do not consider the specific characteristic of the statistical nature of the ground motions and building element responses to determine probability density functions for the damage.

10.6.6 Where the site stability analysis has concluded that there is a possibility of site instability, consideration of the impacts on damageability to the building(s) due to such a failure.

10.6.7 A BD2 level of investigation has moderately low uncertainty. However, if drawings are not available, the reduction in the level of uncertainty compared to BD1 investigation with drawings is reduced.

10.7 *Level BD3 Investigation*—In addition to the observations described in a Level BD2 investigation, a Level BD3 investigation should consist of, but not be limited to, the following:

10.7.1 If drawings are not available or complete, then comprehensive destructive and nondestructive testing meeting the testing requirements of ASCE 41-13 shall be performed.

10.7.2 Estimation of the damage to the building systems and site improvements based on a Level G2 assessment, and compute the PL or SL values for corresponding probabilities of occurrence.

10.7.3 Performance of a full engineering analysis of the building's expected performance, for example, by computer modeling to determine story accelerations and inter-story displacements including possibly both three-dimensional and nonlinear methods to estimate the expected building damage for buildings exhibiting highly irregular structural systems or where the consequence of failure is significant. Where records exist, these should also be used in evaluating past building seismic performance.

10.7.4 Where appropriate, consideration of the soil-foundation-structure interaction.

10.7.5 The user should consider implementing the peer review process to ensure acceptable technical performance.

10.7.6 With a Level BD3 investigation, the building's seismic performance is expected to be characterized with minimal uncertainty. Even with comprehensive testing, if drawings are not available, the reduction in the level of uncertainty compared to BD2 investigation with drawings is reduced.

11. Building Content Damageability Assessment

11.1 *Objective*—The objective of the building content (contents) damageability assessment is to perform an analysis of the earthquake performance of contents within the building. This analysis is concerned with contents that are not part of the building systems.

11.2 *Type and Level of Content Damageability Assessment*—Analyses are recommended to be performed only on a scenario loss (SL) basis, with the specific scenario fully described. Performance of the content damageability assessment should be in conjunction with and at the same level as the building system damageability assessment for the same specified scenario, so that there is a common basis for understanding building and content damageability.

11.3 *Levels of Investigation for Contents Damageability Assessment*—There are four levels of investigation in contents damageability assessment of real estate. They are described as Level C0, Level C1, Level C2, and Level C3.

11.4 *Level C0 Investigation (Screening Level)*—A Level C0 investigation should include no specific evaluation of contents; instead the overall building damage estimate is based on data (tables or graphs) that include an allowance for contents damage. The resource documents on which these estimates are made must be documented. There is a high degree of uncertainty in the results of a Level C0 investigation.

11.5 *Level C1 Investigation*—A Level C1 investigation should consist of, but not be limited to, the following:

11.5.1 A site visit by a Senior or Field Assessor.

11.5.2 A simplified seismic performance evaluation of contents.

11.5.3 Determination of contents damage rates from a generic damage curve(s) (or other data), and modified based on conditions at the study site.

11.5.4 A Level C1 investigation has an inherent moderate uncertainty in its result.

11.6 *Level C2 Investigation*—A C2 Level investigation should consist of, but not be limited to, the following, in addition to those required for a C1 investigation:

11.6.1 A detailed site visit by a Senior or Field Assessor to develop a comprehensive list of contents and to observe characteristics of these contents relative to the investigation.

11.6.2 A level of complexity of evaluation is increased beyond that of the Level C1 investigation.

11.6.3 Evaluation of the major subcategories of contents damage as discrete items, with an allowance for remaining less significant categories.

11.6.4 Consultation with other specialists, as appropriate, since contents damageability analyses address a wide variety of items.

11.6.5 A C2 level of investigation has moderately low uncertainty.

11.7 *Level C3 Investigation*—A Level C3 investigation should consist of, but not be limited to, the following, in addition to those required for a C2 investigation:

11.7.1 A level of complexity of evaluation is increased beyond that of the Level C2 investigation.

11.7.2 Determination of contents damage from a detailed analysis that addresses all significant contents and tenant equipment and recognizes the value and corresponding potential damage of each.

NOTE 7—Specially designed computer software typically would be used to incorporate the probabilistic effects of all damage components.

11.7.3 With a C3 investigation, the building's contents performance is expected to be characterized with minimal uncertainty.

12. Business Interruption Assessment

12.1 *Objective*—The objective of the business interruption assessment is to perform an analysis of the site, building, equipment, contents, inventory systems, infrastructure, interdependent businesses, and all other relevant parameters to determine one or more of the following:

12.1.1 If the building will suffer business interruption from onsite effects such as direct damage to buildings and equipment or loss of critical contents and supplies.

12.1.2 If the building will suffer business interruption from earthquake impacts to other facilities or services not part of the property.

12.1.3 If the building will suffer business interruption from:

12.1.3.1 Earthquake damage to the buildings of interrelated businesses (not necessarily owned or operated by the owner).

12.1.3.2 Lost availability of utility services, transportation modes, supplies, or services.

12.1.3.3 Lost availability or access to interrelated businesses, supplies or materials.

12.1.3.4 Offsite earthquake damage to the infrastructure such as transit systems, power and telecommunications, utilities, water, and waste supply and treatment facilities.

12.2 *Related Investigations*—In addition to its own unique lines of investigation, the evaluation of business interruption should draw upon other related aspects of the scenario loss (SL) analysis, including building damageability, site failure, building stability, contents damageability, and secondary impacts from loss of services or materials from interrelated businesses or suppliers. A business interruption assessment should not be performed unless a building damageability assessment has been performed.

12.3 *Type of Business Interruption Assessment*—Analyses are recommended to be performed only on a SL basis with the specific scenario fully described. Performance of the business interruption assessment requires that the same level assessments for both building damageability and contents damageability be completed for the same specified scenario so that there is a common basis for understanding earthquake impacts on the building(s).

12.4 *Business Interruption Assessment*—This assessment is performed on a scenario basis, that is, the assessment is conducted assuming that damage corresponding to that estimated in the SL building damageability analysis has occurred.

12.5 *Levels of Investigation in Business Interruption Assessment*—There are four levels of investigation in business interruption assessment. They are described as Level B0, Level B1, Level B2, and Level B3. Damageability evaluations that include Levels B2 or B3 evaluations of business interruption should clearly state what effects are included and excluded in the evaluation process.

12.6 *Level B0 Investigation (Screening Level)*—A Level B0 investigation should consist of, but not be limited to, the following for selected elements listed in 12.1:

12.6.1 Estimation of business interruption losses from a loss estimation distribution curve that is representative of a broad industry category, with no consideration for details of the building's location and operation.

NOTE 8—This curve typically uses the overall building damageability value estimate (SL based, including effects of lost interrelated services, supplies or materials) as its sole input parameter.

12.6.2 There is a high degree of uncertainty in the results of a B0 investigation.

12.7 *Level B1 Investigation*—A Level B1 investigation should consist of, but not be limited to, the following:

12.7.1 A site visit by a Senior or Field Assessor.

12.7.2 Performance of a simplified evaluation of business interruption. The Provider should conduct interviews with key building personnel to ascertain the principal modes of operations.

12.7.3 No off-site facilities are visited or evaluated.

12.7.4 Estimation of business interruption losses based on a generic damage curve representative of the industry under investigation.

NOTE 9—This curve typically uses the overall building damageability value estimate as its sole input parameter but may be modified based upon conditions at the site.

12.7.5 The evaluation need address only the major causes of damage or loss and no interdependencies with related off-site processes. If there is a possibility of failure of the supporting soils, this potential effect on business interruption should be noted but not quantified.

12.7.6 A Level B1 investigation has an inherent moderate uncertainty in its result.

12.8 *Level B2 Investigation*—A Level B2 investigation should consist of, but not be limited to, the following:

12.8.1 A detailed site visit by a Senior or Field Assessor.

12.8.2 Evaluation addressing the more significant causes and interdependencies. The building damage now is one parameter of the evaluation; however, the effects of earthquake damage on equipment systems, supplies, and other variables are also taken into account.

12.8.3 Consideration of off-site effects.

12.8.4 Separate estimations of downtime may be prepared for the major functions of a building and then combined into an aggregate for the overall building.

12.8.5 Business interruption calculations should consider the values associated with the principal component processes.

12.8.6 A B2 level of investigation has moderately low uncertainty.

12.9 *Level B3 Investigation*—A Level B3 investigation should consist of, but not be limited to, the following:

12.9.1 Determination of business interruption from a detailed analysis, which addressees all significant interdependencies and all significant contributors to vulnerability.

12.9.1.1 Consideration of off-site effects including interviews of utilities and providers of supplies key to the operation of the building.

12.9.2 Use of logic trees to interpret interdependencies.

12.9.3 Specially developed computer software should be used to incorporate the probabilistic effects of more complex interdependencies in a process that is closely related to reliability analysis.

12.9.4 With a B3 investigation, business interruption is expected to be characterized with minimal uncertainty.

13. Report Requirements

13.1 The results of the investigations should be documented in a written report following the format provided by the User.

13.1.1 The report should include documentation (for example, references, key exhibits, photographs) to support the analysis, opinions, and conclusions found in the report.

13.1.2 All sources of information should be sufficiently documented to facilitate their being referenced or re-observation at a later date.

13.2 *Matters of Interest and Technical Details:*

13.2.1 The report shall include those matters of interest suggested for assessment(s) pursuant to various provisions of the guide.

13.2.2 The report shall specify clearly how seismic risk and hazard are evaluated and represented, what assumptions are made in the seismic risk assessment that could substantially influence the results, and what quantitative level of overall uncertainties there are in the reported methods and results.

13.2.3 The report shall present the technical basis for the specific conclusions reached and should also provide the full set of technical details of the methods and procedures used to determine the loss values in sufficient detail that an Independent Reviewer can validate the appropriateness of the technical decisions and procedures used.

13.2.4 The report shall contain the technical details of the methods used to determine the SL or PL values. This may be given in an appendix.

13.2.4.1 Information provided regarding ground motion and site stability should include: (*1*) the shaking hazard values selected for the subject site and the source of this data, (*2*) the site class (as defined in ASCE 7) selected for the soils at the subject site and the source of this data, (*3*) a description of the method used to account for site class in the shaking hazard values, (*4*) whether or not liquefaction or other site stability hazards exist and if so, were these accounted for in the loss estimates and how.

13.2.4.2 Information should also be provided on how the building damageability was quantified; for example, (*1*) whether or not a model building type was used to characterize the building damageability and if so, what model building type was selected and what was the source of the damage curve, (*2*) what specific structural and non-structural features of the subject building were accounted for and how.

13.2.4.3 If Demand Surge was included in the loss estimates, this should be stated.

13.2.5 The report shall name the Senior and Field Assessor and other persons involved in performing the assessment with an indication of the total time they each committed to the evaluation. The report shall include an appendix with resumes that review their qualifications and expertise of the Senior

Assessor and Field Assessors and other persons performing the seismic risk assessments.

13.2.6 If a computer software seismic loss assessment tool was used in the seismic risk assessment, the report should include sufficient information to uniquely identify the software used, including the vendor, edition, the criteria used, and limitations. To the extent possible, input data and output files should be included as an appendix.

13.2.7 Any specific limitation or exclusions that impact the technical reliability of the conclusions shall be presented in the report.

13.2.8 The report shall contain a statement indicating who can rely upon the report's findings and conclusions.

13.2.9 The report shall contain a statement indicating the Guide E2026 levels of investigation implemented for each assessment reported. All deletions and deviations from this guide, if any, and all additions, if any, shall be listed individually and in detail. The report conclusion should include the following statement: "We have performed a seismic risk assessment for earthquake due diligence assessment in conformance with the scope and limitations of Guide E2026 for a Level [specify] investigation for [insert address or legal description], the property. Any exceptions to, or deletions from, this Guide are described in Section [insert section] of this report. This seismic risk assessment has determined the [loss value determined, for example, SEL] to be [enter %]. The project [meets/does not meet] the building stability and [meets/does not meet] site stability requirements."

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(4) Thiel, C. C., "Probable Maximum Loss Estimation in Earthquakes; An Application to Welded Steel Moment Frames,"*Structural Design of Tall Buildings*, John Wiley, New York, NY, Vol 6, 1997, pp. 183-207.