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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.

[1] This guide is under the jurisdiction of ASTM Committee E06 on Performance of Buildings and is the direct responsibility of Subcommittee E06.25 on Whole Buildings and Facilities.

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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.