INTERNATIONAL

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Standard Practice for
Probable Maximum Loss (PML) Evaluations for Earthquake Due-Diligence Assessments[1,2]

This standard is issued under the fixed designation E2557; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice establishes standard-of-care for evaluation and classification of the financial risks from earthquake damage to real estate improvements for use in financial mortgage transactions and capital investment evaluation. As such, this practice permits a user to satisfy, in part, their real estate transaction due-diligence requirements with respect to assessing and characterizing a property's potential losses from earthquakes. This practice is intended to address only physical damage to the property from site and building response.

1.1.1 Hazards addressed in this practice include earthquake ground shaking, earthquake-caused site instability, including faulting, subsidence, settlement landslides and soil liquefaction, earthquake-caused tsunamis and seiches, and earthquake-caused flooding from dam or dike failures.

1.1.2 Earthquake-caused fires and toxic materials releases are not hazards considered in this practice.

1.1.3 This practice does not purport to provide for the preservation of life safety, or prevention of building damage associated with its use, or both.

1.1.3.1 This practice does not address requirements of any 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 times of construction or modification of the building(s), or both.

1.1.3.2 This practice does not address the 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.

1.1.3.3 This practice does not address the contractual and legal obligations between a provider and a user, and other parties, if any.

1.1.4 It is the responsibility of the owner of the building(s) to establish appropriate life-safety and damage prevention practices and determine the applicability of current regulatory limitations prior to use.

1.2 Considerations not included in the scope: the impacts of damage to contents, loss of income(s), rents, or other economic benefits of use of the property, or from legal judgments, fire sprinkler water-induced damage or fire.

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.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

E2026 Guide for Seismic Risk Assessment of Buildings

2.2 *Other Standards:*[4]

UBC-97 Uniform Building Code, 1997 Edition

IBC International Building Code, current edition

2.3 *ASCE Standards:*[5]

ASCE 7 Minimum Design Loads for Buildings and Other Structures, current edition

ASCE 41 Seismic Evaluation and Retrofit of Existing Buildings, current edition

3. Terminology

3.1 See also definitions in Guide E2026.

3.2 *475-year site ground motions, n*—seismic induced ground motions at a site with approximately: a return period of 475 years, a 10 % probability of exceedance in 50 years, and an annual frequency of 0.21 %. Also referred to as the DBE.

3.3 *field assessor, n*—field assessor, as defined in Guide E2026.

[1] This practice 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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[3] 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.

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

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

3.4 *independent reviewer, n*—independent reviewer, as defined in Guide E2026.

3.5 *lateral load-resisting system, n*—lateral load-resisting system, as defined in Guide E2026.

3.6 *MCE, n*—Maximum Capable Earthquake, as defined in Guide E2026.

3.7 *probable loss (PL), n*—probable loss, as defined in Guide E2026.

3.7.1 *Discussion*—When there are multiple buildings in the seismic risk assessment, then the damageability values for the group of buildings is to be determined as specified in Guide E2026.

3.8 *probable maximum loss (PML), n*—probable maximum loss, as defined in Guide E2026.

3.9 *provider, n*—provider, as defined in Guide E2026.

3.10 *scenario expected loss (SEL), n*—scenario expected loss, as defined in Guide E2026.

3.10.1 *Discussion*—When there are multiple buildings in the assessment then the SEL for the group of buildings is to be determined as specified in Guide E2026, Section 5.3.

3.11 *scenario loss (SL), n*—scenario loss, as defined in Guide E2026.

3.11.1 *Discussion*—When multiple buildings are in the seismic risk assessment, then the SL for the group of buildings is to be determined as specified in Guide E2026, Section 5.3.

3.12 *scenario upper loss (SUL), n*—scenario upper loss, as defined in Guide E2026.

3.12.1 *Discussion*—When there are multiple buildings in the assessment then the SUL for the group of buildings is to be determined as specified in Guide E2026, Section 5.3.

3.13 *SEL475, n*—the scenario expected loss due to the occurrence of 10 %/50-year site ground motions.

3.14 SEL_{MCE}, *n*—the scenario expected loss due to the occurrence of MCE site ground motions.

3.15 *senior assessor, n*—senior assessor, as defined in Guide E2026.

3.16 *significant damage, n*—significant damage, as defined in Guide E2026

3.17 *SUL475, n*—the scenario upper loss due to the occurrence of 10 %/50-year site ground motions.

3.18 SUL_{MCE}, *n*—the scenario upper loss due to the occurrence of MCE site ground motions.

4. Summary of Practice

4.1 The objectives of this practice are as follows:

4.1.1 To synthesize and document good commercial practice for the determination and rating of seismic risk for buildings.

4.1.2 To facilitate standardization of earthquake risk evaluation terminology for financial transactions.

4.1.3 To establish an industry standard for the requirements to evaluate the financial risk for real estate.

5. Significance and Use

5.1 This practice is intended for use as a voluntary standard by parties who wish to undertake the seismic risk assessment of properties. The goal is for users to objectively and reliably compare the financial risks of earthquake damage to buildings, or groups of buildings, on a consistent basis.

5.2 This practice is designed to provide requirements for the evaluation of earthquake damage risk so that technical reports prepared for the evaluation and rating of seismic risk of a building(s) will be adequate for use by other entities. Potential users including, but are not be limited to, those making equity investments, lending, and financial transactions, including securitized mortgage lending by mortgage originators, loan servicers, underwriters, rating agencies, and purchasers of bonds secured by the real estate.

5.3 The use of this practice may permit a user to satisfy, in part, their requirements for due diligence in assessing a property's potential for losses associated with earthquakes for real estate transactions.

6. Due-Diligence Investigation

6.1 The site stability, building stability and building damageability of the property shall be assessed.

6.2 The user shall specify the condition of the property to be evaluated. The seismic performance can be evaluated for the property in its current condition, or as changed by proposed modification of the seismic response of the soils supporting the building or a proposed seismically retrofitted condition of the building(s) or its sections, or any combination of these conditions.

6.2.1 The proposed seismic modifications of the site must be sufficiently described to allow evaluation of the modifications by an Independent Reviewer.

6.2.2 The proposed seismic modifications of the building systems must be sufficiently described to allow evaluation of the modifications by an Independent Reviewer.

6.3 The Guide E2026 level of investigation shall be specified by the user. The same level of investigation should be performed for each type of the seismic risk assessment. Appendix X2 gives guidance on the setting of the level of investigation.

6.4 The qualifications of the Provider shall be specified as required for the level of investigation specified in 6.3 of Guide E2026. The qualifications level must be equal to or higher than the corresponding level specified in 6.2 and 6.3. Appendix X1 gives further guidance on the setting of minimum qualifications.

6.4.1 For an assessment of Level 1 or higher, the qualifications of Senior Assessor and the Field Assessor of the property and its buildings shall be those of Guide E2026 Sections 6.2.3.2 and 6.2.3.3.

6.4.2 Notwithstanding the asserted level of investigation of a report, if the Senior Assessor or the Field Assessor, or both, do not demonstrate the qualifications of Guide E2026 Section 6.2.3.2 and 6.2.3.3, then the report shall be designated a Level 0 report.

6.5 *Seismic Risk Assessment Report*—The findings shall be reported in conformance to the requirements of Guide E2026 for the level of investigation specified by the user in 6.3 and by a provider qualified in accordance with the requirements of 6.4, with the following sections:

6.5.1 A summary that contains the conclusions of the seismic risk assessment:

6.5.1.1 Location of the building(s), characterization of the site and site soils, and gravity and lateral load-resisting systems.

6.5.1.2 Stability determination of each building site under consideration when subjected to the seismic loadings for the building site location and building characteristics as set forth in Section 9 of Guide E2026. Site stability determination need only be qualitative in nature for an SS0 investigation. For SS1 investigations the site stability is a qualitative assessment that includes the implications on damage to the building structural elements. For SS2 and SS3 investigations the site should be considered unstable if significant damage is caused to the building by the site instability.

6.5.1.3 Stability determination of each building under consideration in the seismic loadings for the building site location and building characteristics and for the level of investigation specified, as set forth in Section 8 of Guide E2026.

6.5.1.4 The building damageability values for the building or group of buildings as a whole for the level of investigation specified as set forth in Section 10 of Guide E2026.

(1) PML shall be user-defined. At a minimum, the SEL_{DBE} and SUL_{DBE} shall be reported.

NOTE 1—CMBS industry is currently defining PML as SEL_{DBE}. It is advisable that SEL and SUL values also be reported for MCE events in areas of low and moderate seismicity areas where MCE poses significantly higher risk than the DBE.

6.5.1.5 A specification of the level of investigation for each assessment and a review of the methods used and the personnel engaged.

6.5.1.6 Results for each of the conditions described in 6.2 that apply.

6.5.1.7 Appropriate reliance language for the report and signature. For Level 1 or higher investigations, the professional seal of the provider.

6.5.1.8 All deletions and deviations from this practice (if any) shall be listed individually and in detail.

6.5.1.9 The report conclusion shall include the following statement: "We have performed a probable maximum loss (PML) evaluation for earthquake due diligence assessment in conformance with the scope and limitations of Guide E2026 and Practice E2557 for a Level XX (specify) assessment of [insert address or legal description], the property. Any exceptions to, or deletions from, this practice are described in Section [ ] of this report. This probable maximum loss (PML) evaluation for earthquake due diligence assessment has determined the PML to be [ ]%." PML is defined as [fill in the definition used]. The project [meets/does not meet] the building stability and [meets/does not meet] the site stability requirements.

6.5.1.10 Each report should include a completed Appendix X4.

6.5.1.11 Each report should include a completed Appendix X5.

6.5.2 A body of the report that provides:

6.5.2.1 All detailed reporting information required by Guide E2026, Section 13, including the basis and background for the work performed in support of the conclusions presented in the report.

6.5.2.2 PML values for each building, and, if appropriate, for the group of buildings.

(1) Report of any other information required by the user, which may include business interruption, and contents damageability.

(2) The organization that commissioned the report and the professional liability limitations of the report provider shall be disclosed in the report.

6.5.3 Attachments and appendices to the report as appropriate including detailed resumes of the Senior Assessor and the Field Assessor that demonstrate their qualifications to perform this work as stated in this Practice.

APPENDIXES

(Nonmandatory Information)

X1. GUIDANCE FOR USE OF E2557

INTRODUCTION

This Appendix provides guidance to decision makers for sorting their way through the intricacies of seismic risk assessment. Usually a due-diligence financial decision is posed as *should the transaction be considered further or not*? A PML assessment is commissioned to understand if there is a seismic hazard at the property and the extent of the risk it poses. The process used to complete PML assessments should consider the various sources of uncertainty as well as the financial and other consequences that may arise when a good building is called 'bad' (Type I error), or when a bad building is called 'good' (Type II error). An error of the first type precludes a possibly profitable investment but otherwise is benign in that it does not lead to a loss, whereas the latter error has a higher risk than is nominally acceptable and may lead to large loss. Type II errors lead to unexpectedly higher risks and should be minimized consistent with other objectives of the User. Experience of the ASTM Committee members suggests that the likelihood of Type II errors is highest in (*1*) Level 0 reports, (*2*) reports issued by individuals that are not sufficiently knowledgeable and experienced at any level, and (*3*) reports where the structural documents were not reviewed. If the result of the assessment is unacceptable to the risk profile of the User and the economics of the deal are still attractive, then the determination can only be made to pursue more, better quality and more reliable information and assurance of qualified performers for the specific property. The goal should be to reach conclusions that give reasonable control of Type II errors, but are not so risk adverse as to reject investments that would be prudent and profitable that otherwise have acceptable seismic risk profiles, incorrectly judged to represent a higher risk (Type I errors). Limiting Type I errors to an acceptable level should be a goal as long as the resulting greater Type II errors are not burdensome. Much of the following discussion addresses how to limit the likelihood of an assessment reaching a technically indefensible conclusion.

This discussion is intended to be considered for application to Building Stability, Site Stability and Building Damageability, Building Contents Damageability and Business Interruption Assessments. While much of the discussion focuses on building damage, it applies to all the assessment disciplines by extension.

Practice E2557 in conjunction with Guide E2026, specify minimum requirements to achieve the purpose of evaluating the seismic risk of a proposed real estate commitment. It requires determination of the:

(A) Likelihood of site failure, that is whether faulting, landslides, or liquefaction can occur within the site that can damage the building;
Discussion: One purpose is to limit investments to sites that will not fail, because often the local jurisdictions may not allow reconstruction of buildings at failed site or the market value of the site may be severely impaired in the future because of the site's past failure. The second purpose is to assure that if site failure occurs the damage is within acceptable bounds.

(B) Stability of the building at the Building Code specified levels;
Discussion: While damage repair can be a formidable cost, it is limited by the value of the property. The settlements for death and injury of occupants caused by instability are bounded by net TOTAL worth of the owner, not just the owner's equity and particularly if the owner had prior reason to suspect instability.

(C) Financial risk in the selected scenario; PML (probable maximum loss) of the building or group of buildings, where PML may be defined as the SEL (scenario expected loss) or SUL (scenario upper loss) in the Design Basis Earthquake ground motion, or in other terms that are specific, such as Probable Loss in the Maximum Capable Earthquake.

Discussion: The level of risk must be specified (for example, mean value, or 10 % chance in 50 years), because if absolute certainty is desired, then every building can suffer a 100 % loss, even if highly improbable. The science and technology of building construction and evaluation is not so well-developed that absolute statements can be made.

X1.1 Site Failure

X1.1.1 It is taken as intuitive that investments in structures that are astride faults should warrant special consideration of the acceptability of the building's seismic performance. Similarly, investments in properties with expected site failure due to liquefaction, landsliding, or faulting warrant careful consideration of the implications of such failure. The issue of significance becomes important, when it is noted that seismically-induced liquefaction within a layer of supporting soils could occur, and yet the differential settlement over the building footprint does not result in significant loss to the building and which may be repaired. In other cases the design may have adequately considered liquefaction and provided a foundation that is bearing below the level of site failure. Practice E2557 defines significant damage as damage exceeding 5 %, but this may be set according to the client's needs. This leaves damageability as the essential open discriminant in distinguishing an acceptable transaction from one that is not.

X1.1.2 There are several available tools to evaluate faulting hazard. Since 1972, California has regulations for the investigation of surface fault rupture hazards, with formal zones established around faults deemed active and geologically well defined [Special Publication 42] (**1**).[6] Most other states have implemented at the state or local level, identification of active faults and fault-zones. And the geological literature has identified and mapped most significant faults in all regions. User guidelines may vary, but sites found within such zones in California need not be deemed unstable if the requisite geotechnical investigations have been done and the reports are available, and acceptable set-backs of the foundation from the nearest identified surface fault traces have been established. Other states have somewhat less well-defined programs, and the surface traces of faults may be undefined or undated. Where surface faulting hazards are known or suspected, the involvement of a qualified geotechnical engineer or engineering geologist is recommended.

X1.1.3 There are several available tools to evaluate soil liquefaction. Soil liquefaction may result in loss of bearing strength of soils supporting shallow foundations, differential settlement on flat sites, tilting of buildings, lateral spread and lurching, disruption of utility connections (causing loss of power, water, gas, signal, or sewer), slope failures, flotation of tanks and upheaval of basement slabs. The best source of information is a site-specific geotechnical investigation report, or foundation report. Such reports, typically done as a part of the original design, often characterize the potential for liquefaction at the site and the severity its effects, and recommend steps to mitigate such effects. In the absence of a site-specific geotechnical report, more approximate means may be used. In the State of Washington, the Dept. of Natural Resources provides statewide maps for liquefaction susceptibility [Palmer 2004] (**2**). Since the 1990s, most urban areas in California have been zoned to identify areas that require geotechnical investigation for liquefaction in new construction, and new designs are required to consider liquefaction by ASCE 7, but such zones indicate only the possible presence, but not the degree, of a liquefaction hazard. Other sources (USGS, ABAG, etc.) produce maps presenting approximate degrees of susceptibility (for example, very low, low, moderate, high and very high) based on surface geology, depth to ground water and limited soil borings. Where liquefaction is expected for the scenario ground motions in question, special care is needed in seismic risk assessment, and the involvement of a qualified geotechnical engineer or engineering geologist should be considered.

X1.1.4 There are several available tools to evaluate landsliding hazard. Most state and regional geological surveys have mapped landslide hazards, including past slides, where the natural slope and/or soil materials are prone to sliding, where related to seismic triggering or other causes. These provide a means of identifying slopes whose debris slides could extend into the property under consideration, as well as conditions that warrant design consideration for the building. Slope instability caused by liquefaction of the toe of an embankment, say at a creek or river, is termed lateral spreading and is normally part of the liquefaction assessment. Where landsliding is expected for the scenario ground motions in question, special care is needed in seismic risk assessment, including involvement of knowledgeable professions in this discipline.

X1.2 Practice E2557 Application

X1.2.1 Application of Practice E2557 requires that the User make a number of decisions on: setting the specific definition of the statistical measures of damageability, requirements for the assessor, the Level of Investigation, and selecting the person or institution to do the assessment. The basic premise is to select the criteria to make investment or lending decisions in such a way as to make distinctions between seismically good and bad buildings, and to do this in a manner that is reasoned, measurably reliable, and sufficiently economical such that decisions can be made within the available resources, knowledge and time for them to be made. The requirements for site and buildings stability are well described and have few discretionary variables except the choice of the Level of

[6] The boldface numbers in parentheses refer to a list of references at the end of this standard.

Investigation, which by Guide E2026 should be the same for site and building stability and damageability assessment.

X1.2.2 The two critical decisions for the User are: (*1*) what damageability measure(s) is to be used to estimate the risk and, (*2*) what level of uncertainty in the risk assessment can be tolerated. From these the Level of the Investigation and the selection of the assessor's necessary qualifications follow. After the assessment is presented, the Users must determine if the report meets their requirements for decision making along with the ASTM requirements. This latter issue is addressed in the validation discussion below. With the understanding of how to make decisions on these three issues, Practice E2557 reports can be used with some confidence in making financial decisions and commitments.

X1.3 Selecting the Damage Measure

X1.3.1 While Practice E2557 requires, at a minimum, reporting the SEL, it may be prudent to consider more than a single measure of the risk of a specified property damageability value. This was a central point of the Black Swan, where Taleb (**3**) argued that to do otherwise is to court disaster when the unexpected occurs that was not considered. The Guide E2026 defined damage measures are:

(1) Scenario Loss (SL), which requires a decision about what statistic to use, the SEL or SUL, or some other statistic, as well as the scenario event to be used, and

(2) Probable Loss (PL) requires the return period for exceedance (PL_N) for a given damage level, or the damage level with a stated probability of exceedance in a given time period.

X1.3.2 The SL and PL damageability measures are fundamentally different. SL presents the damage statistics for a given scenario, say the 475-year return period acceleration, or the average ground motion in a specified earthquake of given magnitude on a specified fault. SL values have no explicit return period, (although the scenario earthquake may be associated with a return period for the ground motions). PL values correspond to a specified return period for ground motions, but have no specific earthquake scenario event with which the damage is associated. While the SL gives the damage associated with the defined scenario event alone, the PL gives a damage level associated with a likelihood of exceedance from all earthquakes that may occur in a given time period. SL has the advantage of being easy to understand, while PL gives a better measure of the risk of damage over time.

X1.3.3 The most common SL measures are SEL and SUL. Caution is suggested when using SUL as a sole reported value, since for a single building the ratio of the SUL/SEL may be large, often in excess of 2.0, [Thiel, Kosonen, Stivers, 2012] (**4**) and as noted in Fig. X1.1. For SL the commonly used scenarios are:

(1) A ground motion at the site with a 475-year return period at the site from a probabilistic ground motion hazard analysis. This in the past was designated the design basis earthquake (DBE).

(2) The Maximum Capable Earthquake (MCE) on any nearby fault.

(3) The maximum of the SL for the DBE or other measures of damageability appropriate to the user.

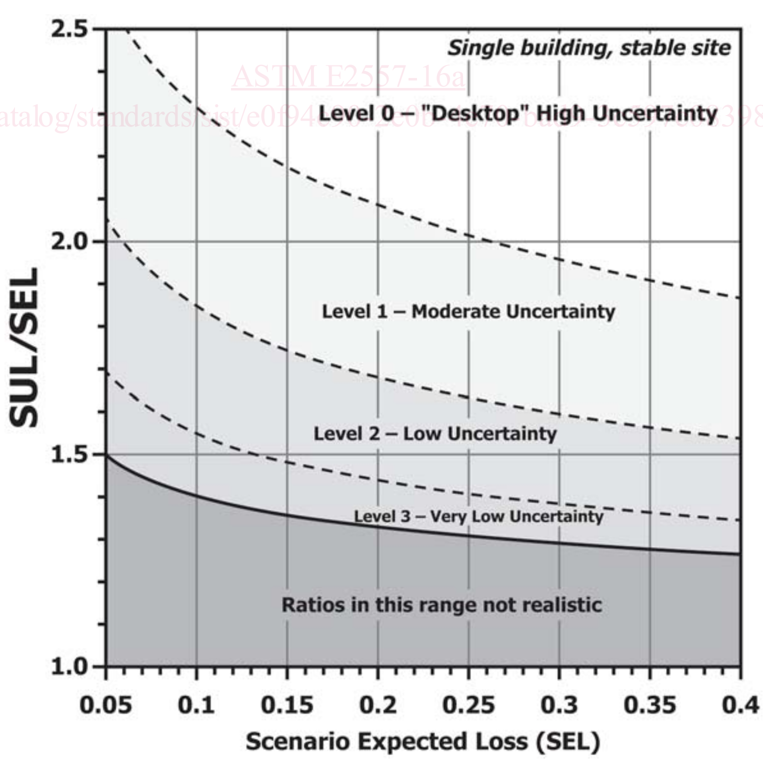

FIG. X1.1 Suggestions of Ranges for SUL/SEL Ratio for Single Building as a Function of Level of Investigation and SEL. The User should inquire of the Provider the basis for damage values not within these ranges to verify that the methods were technically appropriate.