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Relationship Between the Collapse Fragility and Collapse Risk in Existing Buildings in Regions of High and Moderate Seismicity

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by

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This thesis entitled:

Relationship Between the Collapse Fragility and Collapse Risk in Existing Buildings in Regions of High and Moderate Seismicity

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The final copy of this thesis has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above-mentioned discipline.

Abstract

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Relationship between the Collapse Fragility and Collapse Risk in Existing Buildings in Regions of High and Moderate Seismicity

Thesis directed by Research Professor Keith Porter

This thesis aims to identify a relationship between the probability of collapse of existing buildings subjected to MCE/MCE_R shaking and the mean number of collapses per expected building lifetime (τ) in regions of high and moderate seismicity. It encompasses 23 highly seismic locations and 21 moderately seismic locations spread across the United States and considers 35 different building types at each location. The study uses a risk integral to calculate an annual rate of collapse to use for comparison with collapse probabilities, and then uses the scoring system from FEMA 154 as a methodology to consistently compare the collapse rate with their corresponding probabilities of collapse. By identifying and then examining this relationship, this work also provides a more tangible way to interpret the scores assigned to existing buildings through the FEMA 154 procedure.

Contents

Tables

Figures

I. Introduction

Purpose of the Study

The expected seismic performance of an existing building can be quantified in terms of its collapse probability conditioned on a specific level of excitation or in terms of annual frequency of collapse, or other measures. This thesis addresses the relationship between these two. Both of these areas are dependent upon both the location of the existing building, as well as the collapse capacity, or fragility, of the existing building. The most recent update of the NEHRP Provisions identifies a risk integral that uses both of these parameters to quantify risk for new buildings. In "Risk-Targeted versus Current Seismic Design Maps in the Conterminous United States", Luco et al. (2007) explain the development of this risk integral and identify the relationship that exists between the probability of collapse given new design level shaking and the annual rate of collapse-causing earthquakes in a specific location. The purpose of this study is to determine if there is a similar relationship for existing buildings, that is a relationship between the collapse probability (given as a percentage) and the collapse risk (given as a rate) for existing buildings in the United States. It specifically examines the collapse probability of existing buildings based on selected ground motion values (referred to here as fragility) and the mean number of collapses of existing buildings in given locations per expected building lifetime (risk), or more accurately the mean number of collapse-causing earthquakes per expected building lifetime, since a building cannot collapse twice. It aims to find a consistent and identifiable relationship between these two sets of data to simplify seismic risk assessment for those with little to no prior seismic design knowledge; for example, for use in rapid visual screening of buildings for potential seismic hazards (FEMA 154, Applied Technology Council 2002).

II. Literature Review

There are several topics of research that are relevant to this study. These topics include soil site classification, ground motion prediction equations, building collapse fragility, probabilistic seismic hazard, and rapid visual screening of buildings for potential seismic hazards.

Site Classification

In order to calculate seismic hazard at a given location, one must account for the role of soil type in the transmission of seismic waves. The shear wave velocity of a given soil changes the expected spectral accelerations, and thus alters the resulting hazard curves. To further understand the effects of soil classification, two sources were consulted.

Short Note: On the Use of High-Resolution Topographic Data as a Proxy for Seismic Site Conditions (V_{s30})

Wald and Allen (2009) explore the advantages and disadvantages of using higher-resolution digital elevation models (DEMs) to model global seismic site conditions (V_{S30}) in greater detail. They accomplish this by using 3 arcsec resolution and 9 arcsec resolution DEMs along with the USGS National Elevation Dataset to model the seismic site conditions of San Francisco, Los Angeles, and St. Louis. They then compared these predicted V_{S30} values with measured values and values found using Shuttle Radar Topography Mission (SRTM) 30 arcsec DEMs (most common estimation method). Through these tests, Wald and Allen (2009) find that while the higher-resolution DEMs offer more accurate geological and topographical features, the inherent smoothing nature of a less-resolved method allows one to overlook minor surficial perturbations, resulting in more accurate V_{S30} predictions. The novelty of this paper is that it offers an estimate of V_{S30} that relies solely on SRTM data, and does not require geological information or site-specific soil borings. This research is relevant to the thesis topic because the potential damage experienced by structures due to seismic activity is heavily dependent on the seismic conditions of the area in which it is located. Accurate site condition modeling of different areas of the United States is necessary to determine the resulting effects on a specific structure.

Developing a Map of Geologically Defined Site-Condition Categories for California

Wills and Clahan (2006) develop a site soil classification map of Southern California in which regions are determined by specific geologic characterizations, which are then related to NEHRP site classifications. To do so, Wills and Clahan (2006) first sort the available California Geological Survey shear-wave velocity data by geologic characteristic, paying particular attention to and adjusting classifications close to a geologic boundary when necessary. They then generalize these characteristics into clearly defined geologic units and cross-reference the geologic unit of each site with its shear-wave velocity as defined by the California Geological Survey (CGS). Using this data, they construct a composite shear-wave velocity profile for each geologic unit, and then finally redefine (and redraw, when necessary) the site category boundaries on a map of California. The relevance of this paper to the thesis is that the Wills-Clahan map can be used to estimate V_{S30} anywhere in California, without the need for soil boring data.

Ground-Motion Prediction Equations

The present work uses United States Geological Survey (USGS) National Seismic Hazard Maps as its source of both hazard curve data and Maximum Considered Earthquake (MCE) and Risk-Targeted Maximum Considered Earthquake (MCE_R) spectral accelerations. MCE and MCE_R values are the design-level spectral accelerations (measured in g's) used in the uniform hazard design and risk-targeted design, respectively, of new buildings   This data is indeed dependent upon the soil classification process previously mentioned, as well as an earthquake rupture forecast and one or more ground motion prediction equations. The version of the NSHMP used here employs the Next Generation of Attenuation (NGA) Relations, discussed next.

NGA Project

Chiou et al. (2008) present the process and results from the Next Generation of Attenuation (NGA) Relations Project , which is a five-year research program aimed at developing improved earthquake ground motion attenuation relations for shallow crustal earthquakes in the western United States and similar tectonic regions. In order to determine these relations, the authors first developed one common strong-motion database for five different development teams to use to reduce unwarranted model-to-model variation, as well as foster a collaborative effort among seismologists and engineers. This new database filled the data gap in the existing database with recent earthquakes, large earthquakes, and also with new metadata to characterize the site conditions of each record. In four projects included in the NGA effort, four ground-motion models were created and compared, and the models are extrapolated so that they are applicable to all relevant crustal earthquakes in California. This work is important because it offers a uniform and robust updated database for the development of new attenuation relationships, particularly in California.

Probabilistic Seismic Hazard

As this study references hazard curve data and both MCE and MCE_R values, it is necessary to understand the changes that were made to transition from one set of values to the next. The USGS consulted with the NGA Relations Project to develop the "Documentation for the 2008 Update of the United States National Seismic Hazard Maps," which explains the changes that were made to gather the most recent set of hazard curve data.

Documentation for the 2008 Update of the United States National Seismic Hazard Maps

Peterson et al. (2008) provide a new set of USGS National Seismic Hazard Maps (updated from 2002), along with an explanation of their methodology and alterations. The final 2008 update breaks the United States into the Central and Eastern United States (CEUS) and the Western United States (WUS). The WUS is then further divided into the Pacific Northwest, Intermountain West, and California. In the 2008 maps, four different classes of earthquake source models continue to be included in the mapping process (smoothed-gridded seismicity, uniform background source zones, geodetically derived source zones, and faults). The changes through this update include reducing moment rates due to aftershocks and foreshocks, reducing large-magnitude earthquakes to account for earthquakes already counted, altering fault slip rates and fault parameters, adding new recurrence distributions, and reducing certain zone magnitudes and recurrence rates. The attenuation relations and general methodology for the mapping process were also changed. This updated document provides significance because it presents the "best available science" in United States earthquake hazards estimation and the most up-to-date seismic maps.

With the knowledge of how the new mapping presented by the USGS differs from the old, one then needs to understand MCE and MCE_R shaking. This study covers both of these sets of data, so it is necessary to grasp the process used to calculate each set, which is presented in "Risk-Targeted versus Current Seismic Design Maps for the Conterminous United States."

Risk-Targeted versus Current Seismic Design Maps for the Conterminous United States

Luco et al. (2007) propose adjustments to the uniform-hazard portions of the NEHRP-approved seismic design maps. Rather than use a 2% probability of ground motion exceedance in 50 years to calculate design values, they instead use 1% probability of building collapse, which they define as risk-targeted design. They accomplish this by using ground motion hazard curves obtained from USGS National Seismic Hazard Mapping Program (NSHMP) data that are integrated with a structure collapse fragility function (modeled using a lognormal cumulative distribution function) to compute a collapse probability in a given time period for a building with the specified fragility function in a given location. The median value of the fragility function is then adjusted to achieve 1% collapse probability within 50 years. Using an assumed value of the logarithmic standard deviation, they use the median to find the value of shaking intensity (0.2-second or 1.0-second 5%-damped spectral acceleration response) such that, if the fragility function has a 10% collapse probability at that x-value, the risk integral gives 1% collapse probability in 50 years. The x-value becomes the risk-targeted maximum considered earthquake (MCE_R) ground motion value for that location. The work offers a design ground motion for new buildings with the objective that relates to risk (tolerable collapse probability during the design life) rather than fragility (collapse probability conditioned on shaking with specified exceedance frequency). The present work differs from Luco et al. (2007) in that this thesis addresses existing buildings rather than new code-compliant ones, it cannot alter the fragility function, and it does not seek to set collapse risk but rather to evaluate it.

Building Collapse Fragility

This study requires knowledge of collapse capacities of existing buildings as well. The following works present methods for estimating these collapse capacities.

Development of Building Damage Functions for Earthquake Loss Estimation

Kircher et al. (1997) describe the analytical methodology used to estimate probabilities of discrete damage states of existing buildings and then present the building damage functions that were developed for the FEMA earthquake loss estimation methodology encoded in the HAZUS-MH software. They do so by first creating a building classification system, identifying building design and performance levels specific to the seismic zones presented in the 1994 Uniform Building Code, recognizing different functions for structural components and nonstructural components, and defining four different damage states. The 36 different defined building types, which are based on the classification system from the NEHRP Handbook for the Seismic Evaluation of Existing Buildings (FEMA 310), are provided in Table 1. The designation of code levels (building design and performance levels) to specific seismic zones throughout three different time periods is provided in Table 2. Using this template, Kircher et al. (1997) then define building capacity curves for each building type, which are derived from pushover curves. The intersection of each building capacity curve and the demand spectrum with the same effective damping ratio then represents the expected building response performance point. In order to find this performance point, however, several iterations may be necessary since the effective damping ratio changes depending on the location of the performance point. Once inherent damping reductions are accounted for and each performance point is pinpointed through iterations, Kircher et al. (1997) then provide building fragility functions, which predict the probability of reaching or exceeding each damage state. The work provides cumulative distribution function data for the damage states of nearly all existing U.S. building types. This thesis uses the building classification system and parameter values presented by Kircher et al. (1997) as a starting point for the collapse capacities of existing buildings.

Table 1. Building types used in Kircher et al. (1997)

Label	Description	Name	Stories
W1 W2	Wood, Light Frame (≤5,000 sq. ft.) Wood, Commercial, Industrial (>5,000 sq. ft.)		1-2 All
S1L S1M S1H	Steel Moment Frame	Low-Rise Mid-Rise High-Rise	1-3 4-7 8+
S2L S2M S2H	Steel Braced Frame	Low-Rise Mid-Rise High-Rise	1-3 4-7 8+
S3	Steel Light Frame		All
S4L S4M S4H	Steel Frame with Cast-in-Place Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1-3 4-7 8+
S5L S5M S5H	Steel Frame with Unreinforced Masonry Infill Walls	Low-Rise Mid-Rise High-Rise	1-3 4-7 8+
C1L C1M C1H	Concrete Moment Frame	Low-Rise Mid-Rise High-Rise	1-3 4-7 8+
C2L C2M C2H	Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1-3 4-7 8+
C3L C3M C3H	Concrete Frame with Unreinforced Masonry Infill Walls	Low-Rise Mid-Rise High-Rise	1-3 4-7 8+
PC1	Precast Concrete Tilt-Up Walls		All
PC2L PC2M PC2H	Precast Concrete Frame with Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1-3 4-7 8+
RM1L RM1M	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	Low-Rise Mid-Rise	1-3 4+
RM2L RM2M RM2H	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	Low-Rise Mid-Rise High-Rise	1-3 4-7 8+
URML URMM	Unreinforced Masonry Bearing Walls	Low-Rise Mid-Rise	1-2 3+

Table 2. Code level designation used in the UBC (based on seismic zone number)

UBC Seismic Zone	Post-1975	1941-1975	Pre-1941
Zone 4	High-Code	Moderate-Code	Pre-Code
Zone 3	Moderate-Code	Moderate-Code	Pre-Code
Zone 2B	Moderate-Code	Low-Code	Pre-Code
Zone 2A	Low-Code	Low-Code	Pre-Code
Zone 1	Low-Code	Pre-Code	Pre-Code
Zone 0	Pre-Code	Pre-Code	Pre-Code

Cracking an Open Safe: HAZUS Vulnerability Functions in Terms of Structure-Independent Spectral Acceleration

Porter (2009) presents a methodology for creating a non-iterative fatality vulnerability function of a given structure type, that is, without requiring iteration in the capacity spectrum method. He accomplishes this by using data presented in HAZUS-MH to derive equations for the S_a (spectral acceleration), B_{eff} (effective damping ratio), and T (period) of a specific building subject to a defined spectral displacement S_d. He then presents two different sets of equations which use these values to calculate S_sF_a and S_1F_v (the site-amplified, 5%-damped, 0.3-second and 1-second spectral acceleration responses associated with the S_d and S_a values) depending on the structure's period. Finally, he uses these values in a set of damage probability equations for defined damage states, and integrates the product of each probability function and its corresponding damage state to determine the total mean fatality rate. The process presented in this paper is significant because it uses public data and parameters to formulate non-iterative, structure-specific vulnerability functions dependent only on spectral accelerations with a constant damping ratio (5%) rather than performance points in (S_d, S_a, damping ratio) space. The relationship between loss and spectral acceleration offered by Porter (2009) is significant here because it produces lookup tables of fatality-rate fragility functions that can be applied directly to the risk integral, in combination with the hazard data from the NSHMP. The lookup tables are available for all HAZUS-MH building types.

Quantification of Building Seismic Performance Factors: FEMA P695

Another source of collapse fragility functions is offered by Kircher et al. (2009), who build on the Pacific Earthquake Engineering Research Center's Performance-Based Earthquake Engineering methodology (PEER PBEE methodology) for quantifying building system performance and response parameters for seismic design of new structures. The goal of the methodology is to maintain a consistent safety against collapse for new building types that is comparable to the safety against collapse governed by current seismic codes. They do so by presenting a multistep process applicable to any new lateral-force-resisting system to determine that system's seismic performance factors. The process focuses on defining system design requirements, obtaining robust experimental data, creating and grouping archetypes (prototypical system representations) into performance groups, developing nonlinear models of those performance groups, testing and analyzing the nonlinear models, and evaluating the performance. This methodology uses nonlinear dynamic structural analyses to quantify seismic performance of new lateral-force-resisting systems without requiring judgmental and/or qualitative comparisons of existing systems. FEMA P695 presents a method of modeling virtually any type of structure, including the structures on which the thesis focuses.

Existing Building Fragility and Risk Analysis

In evaluating seismic performance using both collapse fragility and collapse risk (probability and annual frequency), it becomes necessary to present a simple method of relating them. The "Rapid Visual Screening of Buildings for Potential Seismic Hazards" developed by FEMA offers such a method.

Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA 154)

Scawthorn et al. (1988, 2002) provide a methodology to quickly screen buildings based on specific visual characteristics to assess their potential seismic hazards. The methodology uses a Basic Structural Hazard Score based on identifying the primary structural lateral-load-resisting system and structural materials of the building. This score is then modified based on the identification of specific performance attributes, providing the screener with a final Structural Score, S. These final S-scores typically range from 0 to 7, and they logarithmically relate to the probability of building collapse under seismic design-level shaking in that

$$collapse\ probability = 10^{-S} \quad \text{and, conversely,} \quad -\log(collapse\ probability) = S$$

Using this scoring system, a screener is able to identify those buildings that are expected to have acceptable seismic performance and those that may require further investigation. The authors recommend that an S-score of 2 or higher be considered acceptable, meaning unlikely to represent an unacceptable risk to life safety and therefore not requiring detailed seismic evaluation. This screening methodology is important because it is a process that is easily understood and can be completed by those with minimal previous seismic understanding or knowledge. It offers a scoring system that quantifies fragility and potential risk in existing buildings in terms that are accessible to the general public. The present work addresses fragility and risk in similar terms to FEMA 154.

III. Procedure

Objective

Through the most recent MCE_R ground motion maps presented in the NEHRP Provisions, the Building Seismic Safety Council (BSSC) has provided a new method of ground-motion mapping that considers regional differences in hazard. In doing so, the Provisions partially account for collapse capacity as well as location-dependent hazard in the design of new buildings. The evaluation of existing buildings subjected to these ground motions, however, is an area that has experienced limited research.

By using Porter (2009), this study categorizes different buildings by type and then defines the collapse capacity of each building type. These custom collapse capacities then yield custom collapse probabilities of specific building types subjected to both MCE and MCE_R shaking. The study also uses the collapse capacity parameterization presented in Porter (2009) along with hazard curve data publicly offered by the USGS to calculate the mean annual frequency of collapse of a specific existing building type in a specific location.

The collection of these two different sets of data then begs the question as to whether or not there is a noticeable relationship between them. If there is indeed a quantifiable relationship, it may then be useful to determine a way to express that relationship for use in, say, FEMA 154. The idea, then, would be that people of all professional backgrounds could both understand and apply the relationship between the data. In order to address these questions and simplify the results, this thesis uses the scoring system presented in FEMA 154 to document and compare the collapse probabilities of 35 different building types subjected to MCE/MCE_R shaking and the mean annual frequency of collapse over the expected lifetime (τ) of those same 35 building types. The analysis is completed for 23 high-hazard locations and 21 moderate-hazard locations across the United States.

It is also important to note that this study focuses on the 5%-damped, 1.0-second period data for both fragility curves and hazard curves. The integrative nature of this study requires that the fragility data and hazard data be derived from models using the same damping and period quantities. The choice of the 1.0-second period is a result of the HAZUS-MH vector intensity data, which is provided at either a 0.3-second period or a 1.0-second period. Given a choice between the two, the 1.0-second spectral acceleration is most significant to HAZUS-MH model building types when analyzing collapse. At the point that these building types reach their final damage states (collapse), their secant period (the period associated with the line in SD-SA space from the origin to the performance point) is usually (though not always) greater than 0.5 seconds, which is near the corner period in the idealized seismic response spectrum. The part of the response spectrum beyond that period is called the "constant velocity" portion of the curve and is a function of the 1.0-second period data. Since the secant period is greater than the spectral acceleration associated with the corner of the response spectrum, the 1.0-second period data is used as the more relevant and useful of the two datasets for collapse fragility functions.

Locations

The adjustment of ground motions from MCE to MCE_R-level shaking presented by Luco et al. (2007) has been made to the entire United States ground motion map, including Alaska, Hawaii, and Puerto Rico. Furthermore, the adjustment of these maps has been presented in the NEHRP Provisions, and was then adopted in the most recent editions of the ASCE 7-10 Standard and the 2012 International Building Code, both of which impact new construction in the entire

United States. As such, for this study it was necessary to consider many different locations spread across the entire country to maintain consistency.

Before selecting specific locations, the seismic design maps from ASCE 7 Standard (2010) can be consulted to gain a better understanding of typical design-level shaking in different regions of the United States. Research with these maps can show that there are several specific regions that exhibit noticeably higher design 1-second response acceleration (S_{D1}) values than the rest of the United States. These regions include areas of the Pacific Northwest, coastal Northern California, coastal Southern California, Utah, the New Madrid region, coastal South Carolina, upstate New York, Alaska, and Puerto Rico. A large portion of the rest of the country has S_{D1} values on the order of 0.1g.

Based on the findings from the seismic design maps, and in an effort to maintain consistency with the current design categories specified in ASCE 7-10, it is necessary to define two different levels of seismicity for this project. Figure 1 shows Table 11.6-2 of the ASCE 7-10, in which four different seismic design categories are defined based on S_{D1}-values and risk category. Since a majority of existing buildings fall under risk categories I, II, and III, this work focuses on the seismic category designation specific to these risk categories rather than risk category IV. This study then defines seismic design category D as "high-hazard" and seismic design categories B and C as "moderate-hazard." Using the corresponding S_{D1}-values presented in Table 11.6-2 of the IBC then, locations in which the S_{D1} is

Table 11.6-2 Seismic Design Category Based on 1-S Period Response Acceleration Parameter

	Risk Category	
Value of S_{D1}	I or II or III	IV
$S_{D1} < 0.067$	A	A
$0.067 \leq S_{D1} < 0.133$	B	C
$0.133 \leq S_{D1} < 0.20$	C	D
$0.20 \leq S_{D1}$	D	D

Figure 1. Copy of Table 11.6-2 (Seismic Design Category) from ASCE 7-10

greater than 0.2g are defined as high-seismicity regions, while those in which the S_{D1} is less than 0.2g but greater than 0.067g are defined as moderate-seismicity regions.

In selecting specific locations, extra emphasis is placed on choosing locations in densely populated areas of the country. By doing so, the central purpose of the NEHRP Provisions, to avoid serious injury and life loss, is maintained. Furthermore, the consideration of a wide range of building types in the study is only relevant in areas where a wide range of building types exist. Using these guidelines while also analyzing all areas of the United States, 23 high-seismicity locations are selected and 21 moderate-seismicity locations are selected. For high-seismicity, the number of locations in each urban area is loosely aligned with the relative population size of that area. For moderate-seismicity, one location is assigned to each urban area and the urban areas are generally selected based on highest population size. This study does not consider whether each location is governed by deterministic ground motions or probabilistic ground motions. The high- and moderate-seismicity locations and their corresponding coordinates are presented in Table 3. The shear wave velocities and design-shaking values for all locations are presented in the Results section. A map of all of the locations except for Anchorage, Alaska is presented in Figure 2.

Table 3. Selected high- and moderate-seismicity locations

High Seismicity					
Point #	Location	State	Placemark #	Latitude	Longitude
1	Seattle	WA	1	47.55	-122.35
2	Seattle	WA	2	47.00	-121.50
3	Portland	OR	1	45.50	-122.70
4	Bay Area	CA	1	38.05	-122.25
5	Bay Area	CA	2	37.75	-122.05
6	Bay Area	CA	3	37.40	-122.25
7	Fresno	CA	1	36.80	-119.80
8	Los Angeles	CA	1	34.60	-118.30
9	Los Angeles	CA	2	34.50	-119.00
10	Los Angeles	CA	3	34.15	-118.50
11	Los Angeles	CA	4	33.80	-118.10
12	San Diego	CA	1	33.50	-117.50
13	San Diego	CA	2	32.80	-117.00
14	Salt Lake City	UT	1	40.85	-111.90
15	Salt Lake City	UT	2	40.50	-111.65
16	Evansville	IN	1	38.00	-87.70
17	Memphis	TN	1	36.50	-89.50
18	Memphis	TN	2	35.40	-90.00
19	Charleston	SC	1	33.20	-80.00
20	Charleston	SC	2	32.75	-80.00
21	Malone	NY	1	45.00	-74.20
22	San Juan	PR	1	18.40	-66.05
23	Anchorage	AK	1	61.20	-149.30

Moderate Seismicity					
Point #	Location	State	Placemark #	Latitude	Longitude
1	Portland	OR	1	45.45	-121.55
2	Sacramento	CA	1	38.45	-120.75
3	Spokane	WA	1	47.65	-117.40
4	Boise	ID	1	43.60	-116.25
5	Las Vegas	NV	1	36.25	-115.25
6	Phoenix	AZ	1	34.25	-112.10
7	Albuquerque	NM	1	35.10	-106.65
8	El Paso	TX	1	31.85	-106.45
9	Denver	CO	1	38.75	-105.60
10	Oklahoma City	OK	1	35.45	-97.50
11	Kansas City	MO	1	39.15	-94.55
12	St. Louis	MO	1	38.85	-90.80
13	Urbana	IL	1	40.10	-88.20
14	Nashville	TN	1	36.00	-86.45
15	Indianapolis	IN	1	39.80	-86.15
16	Louisville	KY	1	38.20	-85.60
17	Atlanta	GA	1	33.75	-84.45
18	Charlotte	NC	1	35.20	-80.85
19	Philadelphia	PA	1	40.00	-75.15
20	New York	NY	1	40.85	-73.95
21	Boston	MA	1	42.50	-71.00

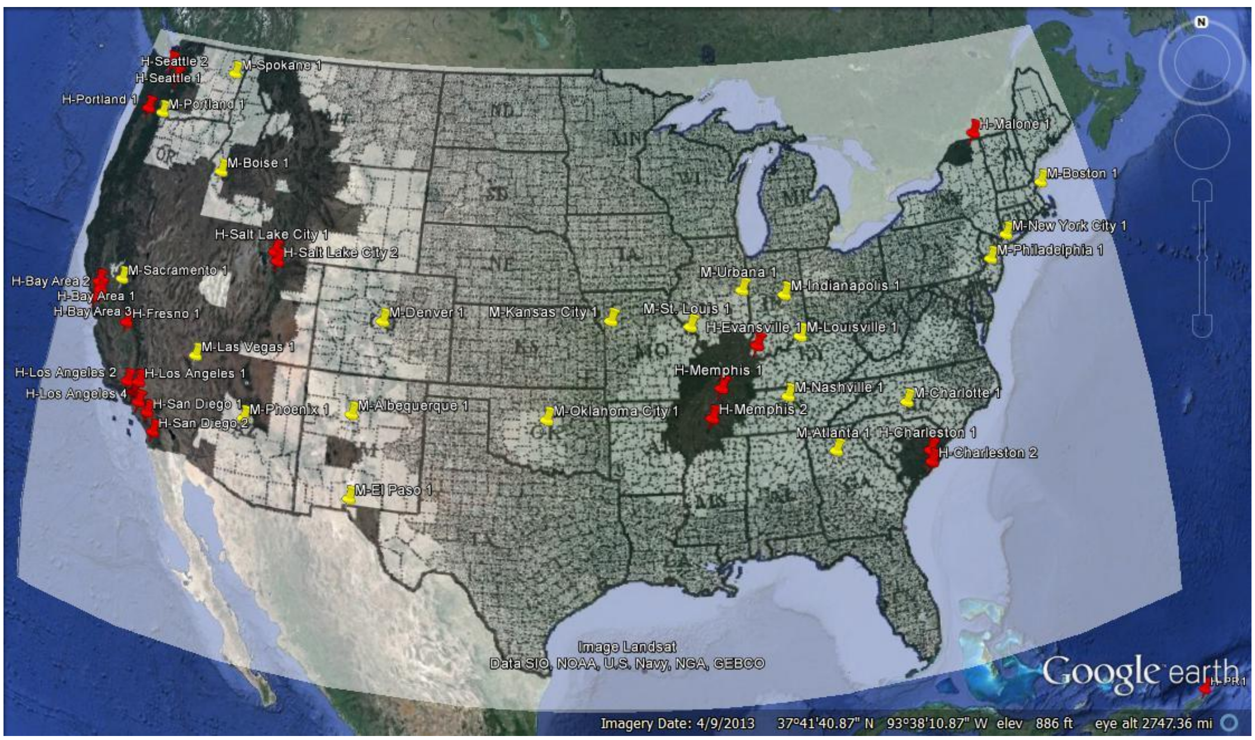

Figure 2. Map of selected locations. High-seismicity locations are shown with red pins while moderate-seismicity locations are shown with yellow pins.

MCE and MCE_R Design Ground Motions

While the seismic design maps do offer a basic, contour-based visual of S_{D1} ground motions in the United States, the USGS does not offer tabulated S_{D1} values by coordinates. The S_{D1} value of a given location is instead calculated using

$$S_{D1} = \frac{2}{3} S_{M1} \text{ and } S_{M1} = F_v S_1$$

where S_1 = 1-second response acceleration and F_v = long-period site coefficient. The USGS does not offer tabulated S_{D1} data, but it does offer tabulated S_1 data. For MCE shaking, S_1 values for each location are gathered using Revision III Ground Motion Data from the USGS, while S_1 values for MCE_R shaking are gathered using Seismic Design Data Sets used in the 2012 International Building Code from the USGS.

The F_v-value of a location, however, is dependent upon that location's soil site classification, as well as its S_1-value. The site classification of a site is determined based on that site's average shear wave velocity in the upper 30 meters of soil (V_{s30}), so the USGS's Custom V_{s30} Mapping tool can be used to find the V_{s30} of each high- and moderate-seismicity location. The mapping tool provides shear wave velocities in terms of meters per second for specified coordinates. The shear velocity for each point is first identified through the mapping tool, and it is then converted into feet per second. Using this shear wave velocity value, the location is then assigned a corresponding NEHRP site classification (A, B, C, D, or E) using Table 20.3-1 from ASCE 7-10. Following the assignment of a site classification, Table 11.4-2 from ASCE 7-10 can be consulted to determine the correct F_v-value for each location.

Hazard Curves

Following the collection of design ground motion values for all of the locations, it is then necessary to gather hazard curve data for all of the locations as well. This data is publicly offered online by the USGS. Since this study focuses on the lateral resistance of existing buildings given hypothetical shaking, it is important to use the most recent hazard curve data that is offered, regardless of whether it is eventually used in comparison with MCE shaking or MCE_R shaking. Given that shaking, the building would be reacting to (and with) its current environment and resultant hazard, not the hazard for which it was initially designed. As such, the hazard curve data for the conterminous United States is gathered using the 2008 Update of Hazard Curve Data from the USGS website. This dataset is presented in terms of spectral acceleration response and mean annual frequency of exceedance for locations at increments of 0.05 degrees latitude and 0.05 degrees longitude. All data is given using the same 20 spectral acceleration values provided at varying increments.

For the two data points located in Alaska and Puerto Rico, the same philosophy of using the most recent data is applied, but the data must be referenced from a different set. The hazard curve data for Alaska has not been updated since 2007, so the 2007 Update provided by the USGS is used for this study. Similarly, the 2003 Update for Puerto Rico is used for hazard curve data.

It is important to note that the hazard curve data offered in the 2008 Update for the conterminous United States, the 2007 Update for Alaska, and the 2003 Update for Puerto Rico all assume a shear wave velocity of 760 meters per second. This corresponds to the boundary between soil site classes B and C. As such, all of the collected hazard curve data require adjustment to account for the soil specific to its location. The spectral acceleration values for each data point at each location must be multiplied by their previously-calculated F_v-values since the B/C site class boundary assumes an F_v-value of 1.0. Following the adjustment of the spectral acceleration values at each location, the resulting hazard curves are plotted with spectral acceleration on the x-axis and annual exceedance probability on the y-axis.

Fragility Data

HAZUS-MH

After gathering hazard curve data for all of the locations, the next step is to determine the collapse capacities to be used in the risk integral. This study uses the data from HAZUS-MH, which is the Federal Emergency Management Agency's (FEMA's) methodology for estimating potential losses from disasters. Porter's (2009) HAZUS-MH-based fragility functions are used for this study. This data includes all of the building types specified in HAZUS-MH except for mobile homes.

Each building type also falls into a category of pre-code, low-code, moderate-code, and high-code, as do the datasets. From 1941 until 1997, the Uniform Building Code employed the use of a Seismic Zone Map of the United States. Each zone is defined by a different zone number ranging from 0 to 4, each of which corresponds to a different code level. These levels have evolved over time for each zone number. As this study focuses on existing buildings, many of which were constructed pre-1997, these code levels are important to consider. Initially, this study focused only on moderate-code building types. The philosophy behind this was that high-code buildings would likely not be a great source of risk, while the risk of moderate-code buildings would be higher. It was also believed that maintaining consistency in the research would prove to be beneficial during analysis. Following analysis, however, it was found that it is perhaps more reasonable to also consider low-code data for moderate-hazard locations.

Beyond code levels, the author determined it necessary to include all HAZUS-MH building types (except for mobile homes) in the study in order to present credible final analysis. As such, the building types used for fragility data collection are presented in Tables 4 and 5. The code levels are included as the hyphenated, lower-case attachments to each building type.

Table 4. Building types used for high-seismicity locations in this study

Material	HAZUS-MH Building Types Used in Study		
	Low-Rise	Mid-Rise	High-Rise
Wood	W1-m	-	-
	W2-m		
Steel	S1L-m	S1M-m	S1H-m
	S2L-m	S2M-m	S2H-m
	S3-m		
	S4L-m	S4M-m	S4H-m
	S5L-l	S5M-l	S5H-l
Concrete	C1L-m	C1M-m	C1H-m
	C2L-m	C2M-m	C2H-m
	C3L-l	C3M-l	C3H-l
Precast Concrete	PC1-m		
	PC2L-m	PC2M-m	PC2H-m
Reinforced Masonry	RM1L-m	RM1M-m	-
	RM2L-m	RM2M-m	RM2H-m
Unreinforced Masonry	URML-l	URMM-l	-

Table 5. Building types used for moderate-seismicity locations in this study

Material	HAZUS-MH Building Types Used in Study		
	Low-Rise	Mid-Rise	High-Rise
Wood	W1-l	-	-
	W2-l		
Steel	S1L-l	S1M-l	S1H-l
	S2L-l	S2M-l	S2H-l
	S3-l		
	S4L-l	S4M-l	S4H-l
	S5L-l	S5M-l	S5H-l
Concrete	C1L-l	C1M-l	C1H-l
	C2L-l	C2M-l	C2H-l
	C3L-l	C3M-l	C3H-l
Precast Concrete	PC1-l		
	PC2L-l	PC2M-l	PC2H-l
Reinforced Masonry	RM1L-l	RM1M-l	-
	RM2L-l	RM2M-l	RM2H-l
Unreinforced Masonry	URML-l	URMM-l	-

Fragility Curve Fitting

HAZUS-based collapse probability is partly a function of both magnitude and distance, which affect duration, hysteretic energy dissipation, and hence effective damping ratio. Porter (2009) offers fragility functions for HAZUS's three magnitude ranges (M<5.5, M>7.5, and intermediate) and four distance values (10, 20, 40, and 80 km). Since hazard curves are not accompanied by magnitude or distance data, the author used intermediate values: medium magnitude (5.5 to 7.5) and medium distance (20 km). Since the fragility curves represent the characteristics of the building, regardless of location, no adjustments to the spectral acceleration values are required. The fragility curves are presented as cumulative distribution functions in terms of 5%-damped, 1-second period spectral accelerations and their corresponding collapse probabilities. Each curve is evaluated at 41 to 51 different points. The spectral acceleration values used for the fragility data, however, do not correspond with those used for the hazard curve data. Since one goal of this study is to evaluate a risk integral for each building type at each location, it is necessary to fit either the hazard curve data or the fragility data with a function such that one set of spectral accelerations can be used through the integration process. Since the fragility function data is presented in the form of multiple cumulative distribution functions, it seemed most likely to follow a lognormal distribution. As such, an equation is determined to define each set of fragility function data.

The first step in the curve-fitting of the fragility functions is to normalize each curve, such that all of the curves asymptote to 1.0. The reason for this is that Porter's (2009) HAZUS-based fragility functions express the probability that a particular location within a building would experience collapse as a function of ground motion, as opposed to the probability that collapse occurs at all, anywhere in the building, as a function of ground motion. The fraction of the building area experiencing collapse is taken as constant, so normalizing the fragility function by that constant yields an estimate of collapse probability anywhere in the building. This normalization is achieved by dividing each probability by the maximum probability provided in its respective dataset. The lognormal cumulative distribution function of a set of spectral accelerations can then be represented by:

$$F(x) = \Phi\left(\frac{\ln\left(\frac{x}{\theta_d}\right)}{\beta_d}\right) = \Phi\left(\frac{\ln(x) - \ln(\theta_d)}{\beta_d}\right)$$

where x = particular spectral acceleration, Θ_d = median spectral acceleration associated with collapse, β_d = logarithmic standard deviation, and Φ(s) represents the standard normal cumulative distribution function evaluated at s. For this study, the particular spectral acceleration (x) represents the independent variable in the function. The median spectral acceleration (Θ_d) occurs where each normalized fragility curve reaches a collapse probability of 0.5. The datasets for each building type are then linearly interpolated to solve for the spectral accelerations at the 50th-percentile collapse capacities. The equation for logarithmic standard deviation (β_d) is then:

$$\beta_d = \frac{\ln\left(\frac{x}{\theta_d}\right)}{z} = \frac{\ln(x) - \ln(\theta_d)}{z}$$

where z = standard normal distribution z-score, which is dependent upon the probability related to a specific x-value being used in the equation. In the case of this study, the chosen probability is 0.1 (i.e. the 10th-percentile collapse capacity). Similarly to the 50th-percentile collapse capacity, the datasets for each building type are again linearly interpolated to solve for their respective spectral acclerations at the 10th-percentile collapse capacities. Using 0.1, the corresponding z-score is found on a standard normal distribution z-score chart again by using linear interpolation. Since the 10th-percentile collapse capacity is used for all building types, the z-score remains constant for all building types as well. Using the standard normal distribution function in Microsoft Excel, along with the calculated Θ_d-, β_d-, and z-values, a lognormal distribution curve is then fitted to each given fragility curve. The lognormal distribution curve uses the same spectral acceleration x-values that are provided in the initial fragility data.

Kolmogorov-Smirnov Test – Standard Values and Monte Carlo Values

Porter's (2009) fragility functions are nonparametric, which leads to the question of whether a lognormal distribution reasonably fits them. For this study, the Kolmogorov-Smirnov goodness-of-fit test is employed to test accuracy. At each spectral acceleration value, the following equation is used to find the difference between the fragility data and the lognormal data:

$$D = K.S.\ Statistic = |F(x) - Normalized\ Probability(x)|$$

For each building type, the maximum Kolomogorov-Smirnov statistic is then identified and tabulated. Furthermore, the total number of data points from each building type is identified and tabulated as well. When the total number of data points exceeds 35, the standard Kolmogorov-Smirnov test presents the following inequality against a critical K.S. statistic value to evaluate the accuracy of fit:

$$95\%\ goodness - of - fit = \left(D_{max} \leq \frac{1.36}{\sqrt{N}}\right)$$

Lilliefors (1967), however, argues that when certain parameters of the distribution must be estimated from the sample, then the Kolmogorov-Smirnov test produces results that are conservative. He then performs a Monte Carlo calculation and presents a table with adjusted critical K.S. statistic values. Since both the median and lognormal standard deviations for the fragility curves are estimated through linear interpolation, it was determined that this method applies. The adjusted inequality from Lilliefors is:

$$95\%\ goodness - of - fit = \left(D_{max} \leq \frac{0.886}{\sqrt{N}}\right)$$

Both the standard and adjusted K.S. statistic inequalities are applied to all building types to ensure that each lognormal curve is indeed an accurate fit for the given fragility data.

Probability of Collapse

Assuming the fragility functions pass the Kolmogorov-Smirnov test, each building type then has a lognormal distribution that serves as an accurate representation of its collapse capacity. The next step is to calculate the probability of collapse of each building type in each location given S_{D1} shaking values. Since the S_{D1}-values for MCE and MCE_R shaking are already calculated at this point, this process is relatively straightforward. Using the lognormal distribution function for each building type, the collapse probabilities are calculated and tabulated at the (2/3)MCE and (2/3)MCE_R spectral acceleration values for each location using:

$$P_{MCE} = \Phi\left(\frac{\ln\left(S_{D1(MCE)}\right) - \ln(\theta_d)}{\beta_d}\right)$$

$$P_{MCER} = \Phi\left(\frac{\ln\left(S_{D1(MCER)}\right) - \ln(\theta_d)}{\beta_d}\right)$$

where P_{MCE} = collapse probability due to (2/3)MCE shaking, P_{MCER} = collapse probability due to (2/3)MCE_R shaking, $S_{D1(MCE)}$ = S_1-value specific to (2/3)MCE shaking, and $S_{D1(MCER)}$ = S_1-value specific to (2/3)MCE_R shaking. The reason for using S_{D1}-values rather than S_{M1}-values is that this research was specifically motivated by aspects of the 2nd edition and early 3rd edition of FEMA 154. These editions use S_{D1}-values to represent the fragility of existing buildings.

Application of Risk Integral

With parameterized collapse capacity curves for each building type and hazard curve data for each location, it is then possible to solve a risk integral to determine the annual frequency of collapse for a building type in a given location. The risk integral that is used is equivalent to the risk integral employed in the risk-targeted design maps by Luco et al. (2007). The difference is that the present work uses fragility functions that vary by building type and are not adjusted, rather than adjusting a fragility function to find the MCE_R value associated with 10% conditional collapse probability that results in 1% marginal collapse probability in 50 years, as used by Luco et al. (2007). The risk integral that is used to solve for annual frequency of collapse is:

$$\lambda = \int_0^\infty \left| \left(\frac{dG(x)}{dx}\right) (F(x)) \right| dx$$

where G(x) = hazard curve and F(x) = fragility. The integral is evaluated numerically, using the equation offered in Porter et al. (2006), which is applied to the present problem as follows. Given n+1 values of spectral acceleration, denoted as x:

$$\lambda = \sum_{i=1}^{n} \left(F_{i-1} G_{i-1} \left(1 - e^{m_i \Delta x_i}\right) - \frac{\Delta F_i}{\Delta x_i} G_{i-1} \left(e^{m_i \Delta x_i} \left(\Delta x_i - \frac{1}{m_i} \right) + \frac{1}{m_i} \right) \right)$$

where

$$\lambda = annual\ frequency\ of\ collapse \quad \Delta x_i = x_i - x_{i-1} \quad \Delta F_i = F_i - F_{i-1} \quad m_i = \frac{ln(G_i/G_{i-1})}{\Delta x_i}$$

Using this equation and the set of discrete spectral accelerations from the hazard curve data specific to each location, an annual frequency of collapse is then calculated and tabulated for each building type in each location.

Scoring Methodology

Scoring System

Following the collection and tabulation of the collapse probabilities and annual frequencies of collapse of each building type in each location, the challenge then is finding a way to relate the two. It was desired for this work to make the terms accessible to a lay audience, particularly users of FEMA 154. That work presents a scoring system that relates the scores assigned through visual screening to the probability of collapse of a building subjected to design-level shaking. Using the inverse logarithmic relationship, this study assigns each building type a score S or S' based on the probabilities of collapse due to MCE or MCE_R shaking, respectively. The equations used to calculate S and S' are:

$$S = -log_{10}(P_G)$$

$$S' = -log_{10}(P_R)$$

For ease of comparison, a similar inverse logarithmic scale is used to express the calculated annual frequencies of collapse. Rather than using the probability of collapse, however, the scoring template instead uses the product of the annual frequency of collapse and the expected lifetime of a building in years. This risk-based score, S_R, is calculated using:

$$S_R = -log_{10}\big((\lambda)(\tau)\big)$$

where λ = the annual frequency of collapse and τ = the lifetime of a building in years. The real lifetime of a building is highly uncertain. Some buildings become functionally obsolete and are demolished after limited years of use, while others may exist for centuries. It is important to note that the value used for tau can have a substantial impact on the risk-based score. For a building with an annual frequency of collapse (λ) of $1.0e^{-6}$ collapses/year, tau-values of 50, 150, and 500 years result in risk-based scores of 4.3, 3.8, and 3.3, respectively. For this study, the τ is taken to be 150 years. While the product of λ and τ provides a frequency rather than a probability, the purpose of using this scoring system for both probabilities and frequencies is to present a method in which to compare and relate fragility and risk.

Score Comparison

In order to compare the resulting scores of each building type in each location, the differences between the risk-based score and the MCE- and MCE_R-based scores are calculated and tabulated. These differences are defined as performance modification factors, PMF and PMF', respectively:

$$PMF = S_R - S$$

$$PMF' = S_R - S'$$

These PMF- and PMF'-values represent the level of difference that exists between the probability of collapse of a specific building type in a specific location given MCE or MCE_R design-level shaking and the frequency of collapse of a specific building type in a specific location over the span of 150 years. A PMF-value of 0 means that both the probability of collapse given MCE design-level shaking and the 150-year frequency of collapse produce the same S-score. This means (generally) that the likelihood of that building type in that location collapsing over the span of 150 years is equal to the probability of collapse given MCE design-level shaking. Since the scale is logarithmic, however, a PMF-value of 1 means that the likelihood of that building type in that location collapsing over the span of 150 years is one order of magnitude (0.1 times) less than the probability of collapse given MCE design-level shaking.

In many cases, especially for moderate-hazard locations, the values of PMF and PMF' tend to stray away from 0, in both the positive and negative directions. In an effort to understand why this occurs, discrepancy values D and D' are defined for the purposes of this study. The equations for these D-values are:

$$D = \frac{(S_{M1})_{MCE}}{c_{10\%}}$$

$$D' = \frac{(S_{M1})_{MCE_R}}{c_{10\%}}$$

where $(S_{M1})_{MCE}$ = 1-second spectral acceleration based on MCE shaking, $(S_{M1})_{MCE\_R}$ = 1-second spectral acceleration based on MCE_R shaking, and $c_{10\%}$ = 10^{th} – percentile collapse capacity of a given building type based on the fragility curve for that building type. The significance of the 10^{th}-percentile collapse capacity is that it represents the S_{M1}-values used for MCE_R design. After adjusting the median collapse capacity of each fragility curve such that the risk of collapse equaled 1% in 50 years, Luco et al. (2007) used the resulting 10^{th}-percentile collapse capacity as the value for S_{M1}. By investigating the ratio between S_{M1} and the $c_{10\%}$-values of the fragility curves from this study, conclusions can be drawn about how this ratio affects PMF and PMF'.

IV. Results

High-Seismicity Locations

Shear Wave Velocities & Soil Site Classifications

The shear wave velocities provided in meters per second by the USGS mapping tool for all high-seismicity locations are shown in Table 6. Also included in these tables are the converted shear wave velocities in feet per second and their corresponding site classifications.

Table 6. Shear wave and site class data for high-seismicity locations

High Seismicity			
Location	V_{s30} (m/s)	V_{s30} (ft/s)	Site Class
Seattle 1	469	1539	C
Seattle 2	760	2493	B
Portland 1	546	1791	C
Bay Area 1	391	1283	C
Bay Area 2	437	1434	C
Bay Area 3	721	2365	C
Fresno 1	754	2474	C
Los Angeles 1	760	2493	B
Los Angeles 2	194	636	D
Los Angeles 3	466	1529	C
Los Angeles 4	206	676	D
San Diego 1	599	1965	C
San Diego 2	276	906	D
Salt Lake City 1	454	1490	C
Salt Lake City 2	718	2356	C
Evansville 1	297	974	D
Memphis 1	237	778	D
Memphis 2	212	696	D
Charleston 1	207	679	D
Charleston 2	250	820	D
Malone 1	322	1056	D
San Juan 1	272	892	D
Anchorage 1	760	2493	B

Design Shaking Values

Table 7 presents the S_1-, F_v-, S_{M1}-, and S_{D1}-values for all high-seismicity locations based on MCE shaking. Similarly, Table 8 presents the S_1-, F_v-, S_{M1}-, and S_{D1}-values for all high-seismicity locations based on MCE_R shaking.

Table 7. S_1-, F_v-, S_{M1}-, and S_{D1}-values for high-seismicity locations subjected to MCE shaking

MCE				
High Seismicity				
Location	S_1 (g)	F_v	S_{M1} (g)	S_{D1} (g)
Seattle 1	0.504	1.30	0.655	0.437
Seattle 2	0.295	1.00	0.295	0.197
Portland 1	0.385	1.41	0.545	0.363
Bay Area 1	0.518	1.30	0.674	0.449
Bay Area 2	0.690	1.30	0.897	0.598
Bay Area 3	1.233	1.30	1.602	1.068
Fresno 1	1.269	1.30	1.650	1.100
Los Angeles 1	1.051	1.00	1.051	0.701
Los Angeles 2	0.179	2.08	0.373	0.249
Los Angeles 3	0.540	1.30	0.702	0.468
Los Angeles 4	0.429	1.57	0.674	0.450
San Diego 1	0.331	1.47	0.487	0.324
San Diego 2	0.241	1.92	0.462	0.308
Salt Lake City 1	0.643	1.30	0.835	0.557
Salt Lake City 2	0.249	1.55	0.387	0.258
Evansville 1	0.191	2.04	0.389	0.259
Memphis 1	1.183	1.50	1.775	1.183
Memphis 2	0.470	1.53	0.720	0.480
Charleston 1	0.659	1.50	0.988	0.659
Charleston 2	0.348	1.70	0.593	0.395
Malone 1	0.125	2.30	0.287	0.192
San Juan 1	0.294	1.81	0.532	0.355
Anchorage 1	0.632	1.00	0.632	0.422

Table 8. S_1-, F_v-, S_{M1}-, and S_{D1}-values for high-seismicity locations subjected to MCER shaking

MCE_R				
High Seismicity				
Location	S_1 (g)	F_v	S_{M1} (g)	S_{D1} (g)
Seattle 1	0.589	1.30	0.765	0.510
Seattle 2	0.355	1.00	0.355	0.236
Portland 1	0.431	1.37	0.590	0.393
Bay Area 1	0.600	1.30	0.780	0.520
Bay Area 2	0.605	1.30	0.787	0.524
Bay Area 3	1.249	1.30	1.624	1.083
Fresno 1	1.164	1.30	1.513	1.009
Los Angeles 1	1.102	1.00	1.102	0.735
Los Angeles 2	0.256	1.89	0.484	0.322
Los Angeles 3	0.723	1.30	0.939	0.626
Los Angeles 4	0.567	1.50	0.851	0.567
San Diego 1	0.462	1.34	0.618	0.412
San Diego 2	0.336	1.73	0.581	0.387
Salt Lake City 1	0.661	1.30	0.859	0.573
Salt Lake City 2	0.285	1.52	0.431	0.288
Evansville 1	0.208	1.98	0.413	0.275
Memphis 1	1.113	1.50	1.670	1.113
Memphis 2	0.483	1.52	0.732	0.488
Charleston 1	0.669	1.50	1.004	0.669
Charleston 2	0.363	1.67	0.608	0.405
Malone 1	0.142	2.23	0.316	0.211
San Juan 1	0.382	1.64	0.625	0.416
Anchorage 1	0.698	1.00	0.698	0.465

Hazard Curves

Figure 3 shows the hazard curves for each of the high-seismicity locations. This plot uses a logarithmic scale on the y-axis to show where the curves intersect major annual exceedance probabilities. This plot also includes a black dashed line, which represents the 2% in 50 years probability of exceedance previously used to determine MCE design-level shaking.

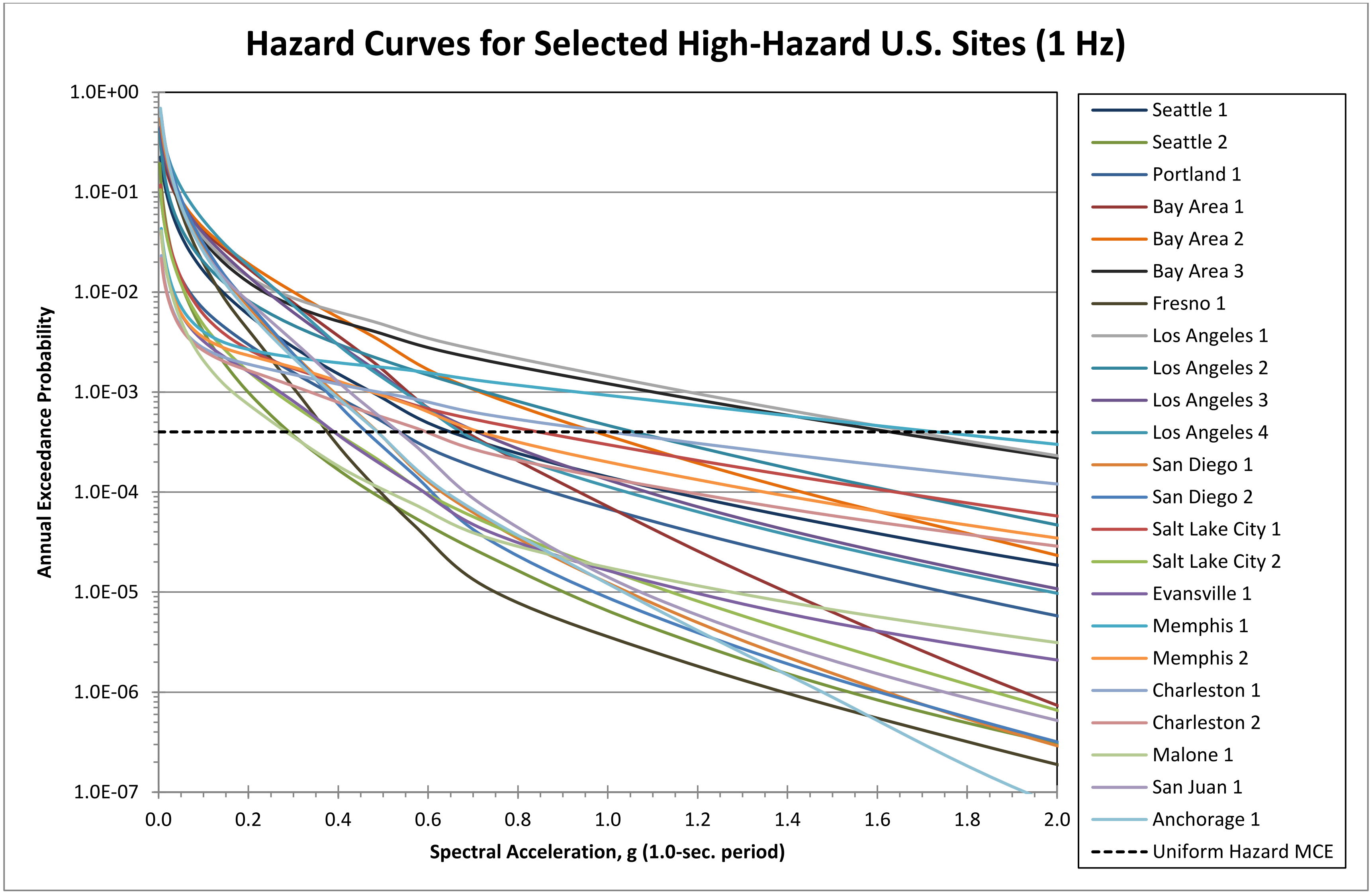

Figure 3. Hazard curves for all high-seismicity locations

Provided Fragility Curve Data – Moderate Code

Figures 4 - 6 show a sample set of fragility curve points from Porter (2009) for a concrete moment frame lowrise, midrise, and highrise building, respectively, subjected to moderate code. Figure 7 presents a comparison among all three height-specific fragility curve datasets for a concrete moment frame building subjected to moderate code. The points represent the expected probabilities of collapse of a given location within each type of building. These functions were developed under the assumption that typically entire buildings do not collapse, but rather fractions or areas of buildings do, which is why the probabilities asymptote to values that are less than 1.0.

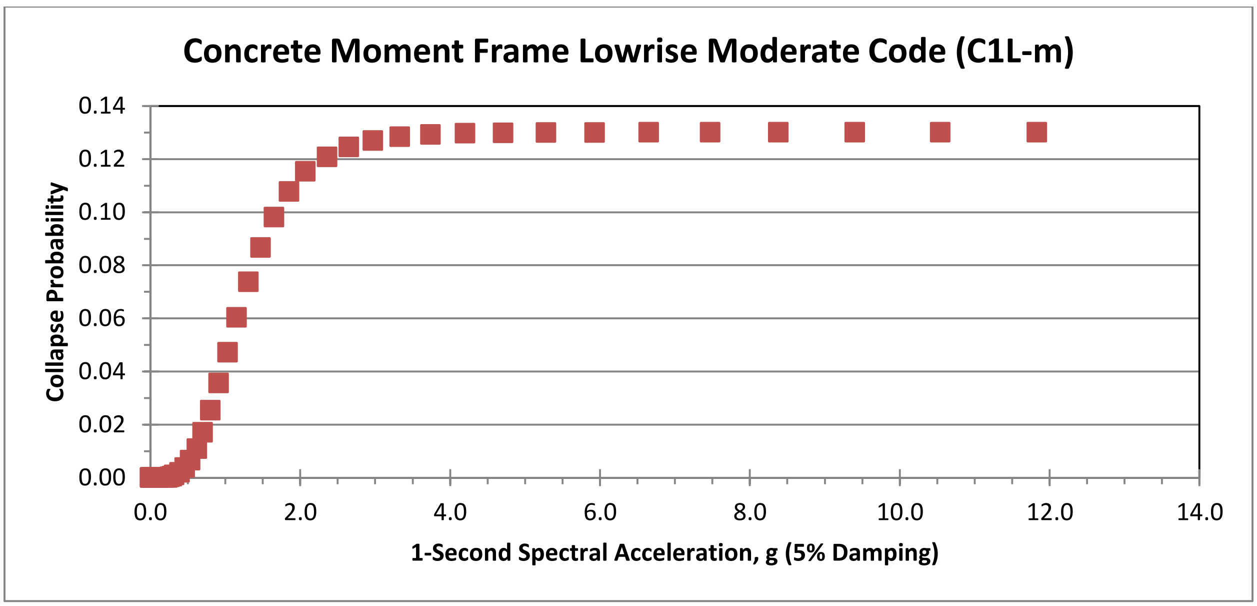

Figure 4. Fragility data for an existing lowrise concrete moment frame building subjected to moderate code

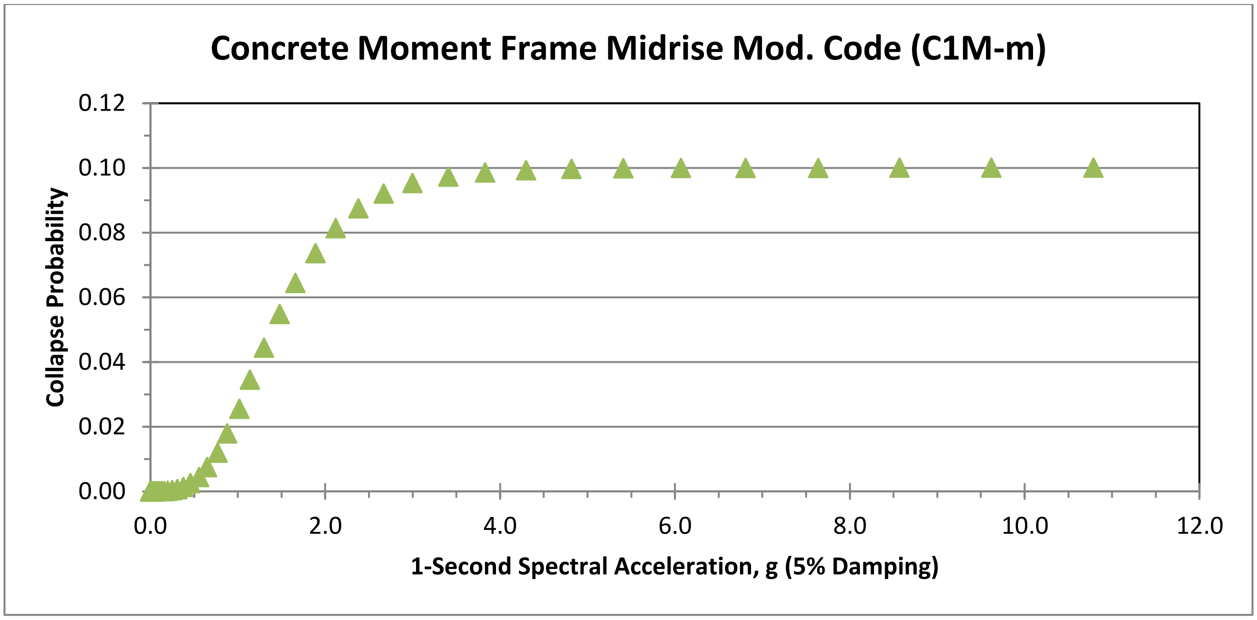

Figure 5. Fragility data for an existing midrise concrete moment frame building subjected to moderate code

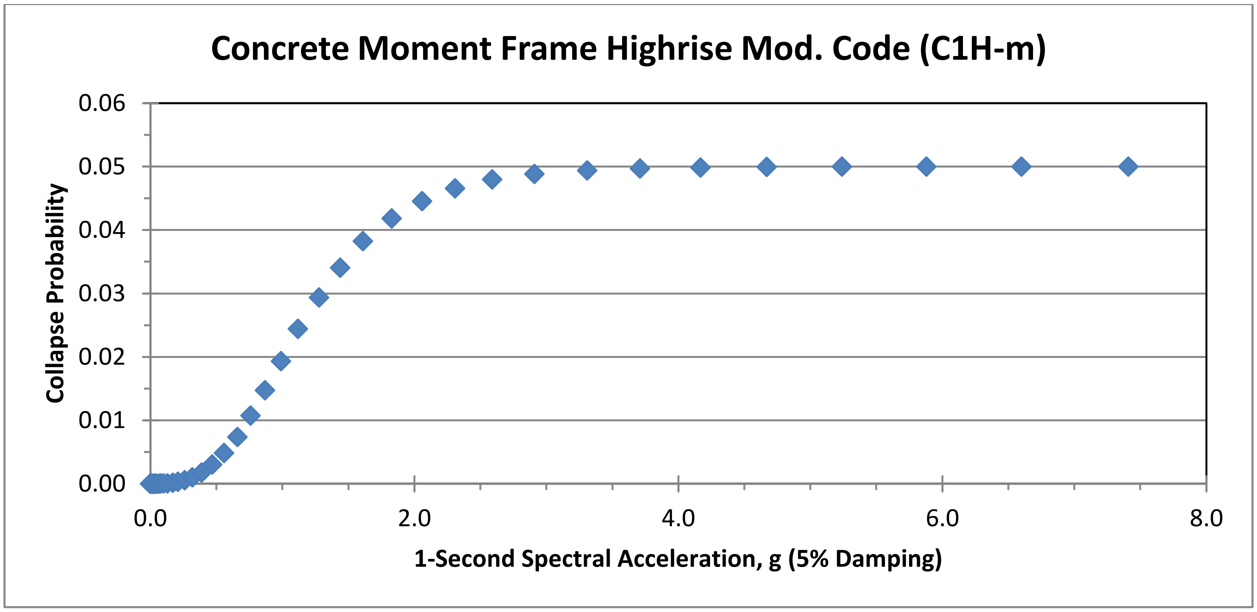

Figure 6. Fragility data for an existing highrise concrete moment frame building subjected to moderate code

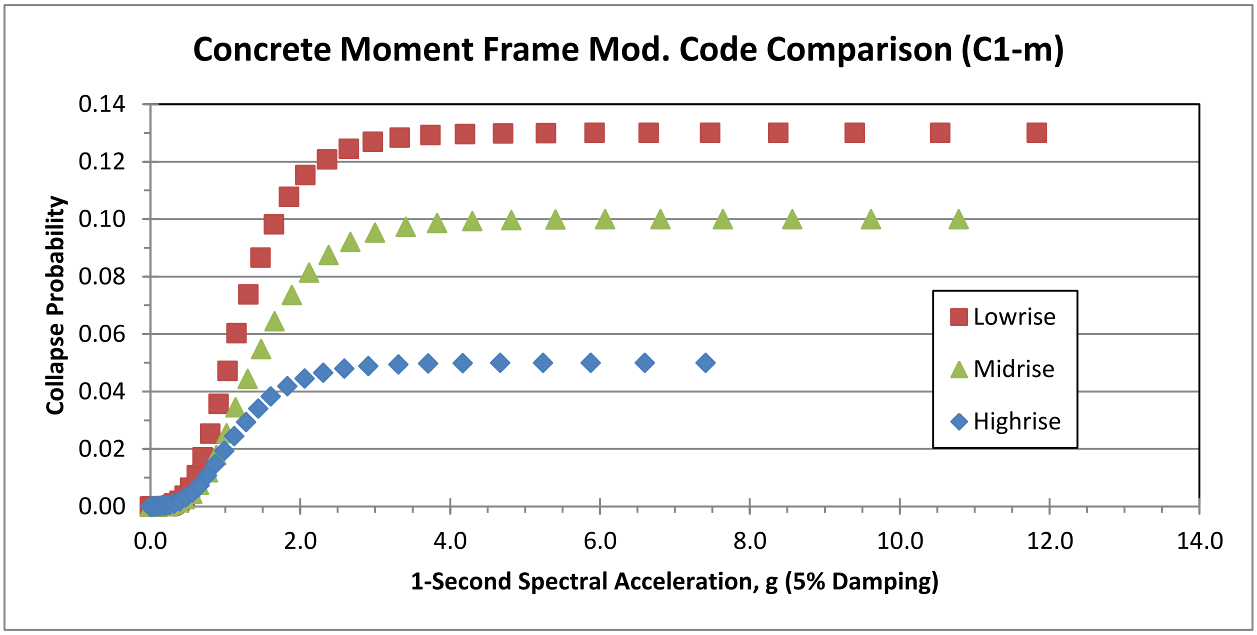

Figure 7. Fragility data comparison for existing lowrise, midrise, and highrise concrete moment frame buildings subjected to moderate code

Fitted Lognormal Curve – Moderate Code

Figures 8 - 10 present graphical comparisons of the normalized fragility data provided by HAZUS-MH and their corresponding fitted lognormal curves. The figures are again specific to a lowrise, midrise, and highrise concrete moment frame building subjected to moderate code.

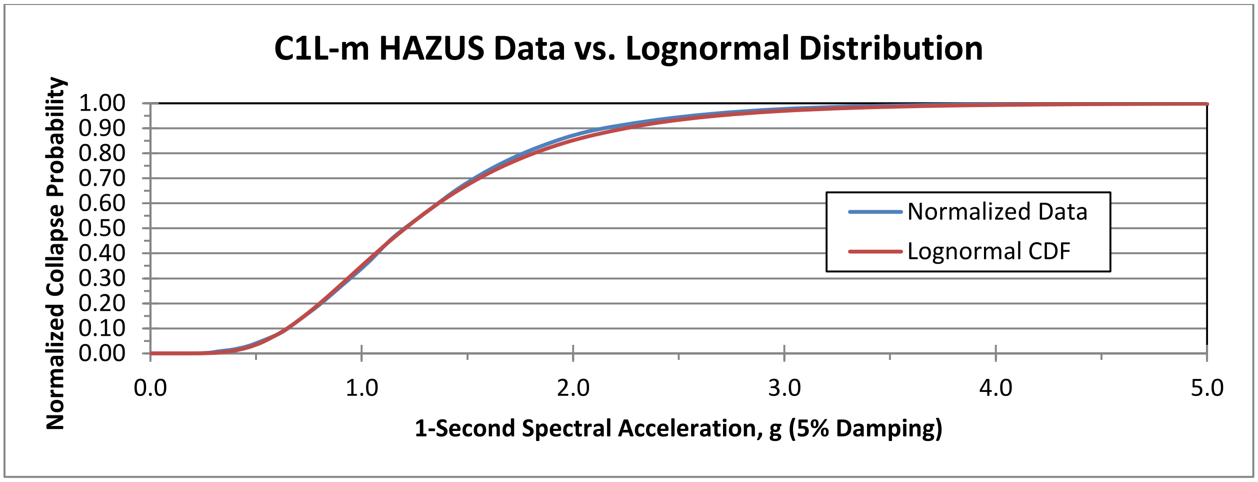

Figure 8. Fitted lognormal curve to data from lowrise concrete moment frame building subjected to moderate code

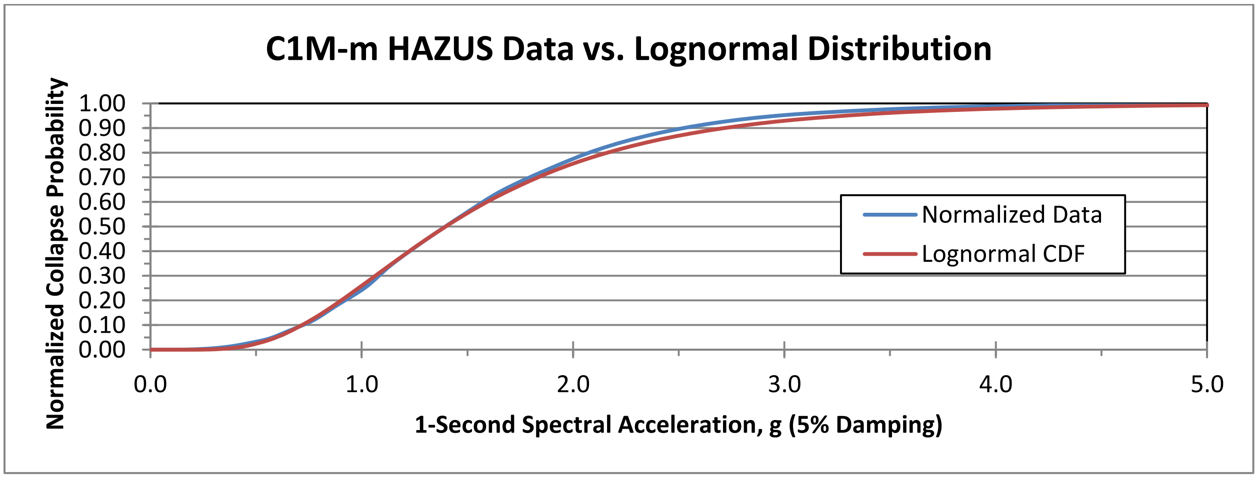

Figure 9. Fitted lognormal curve to data from midrise concrete moment frame building subjected to moderate code

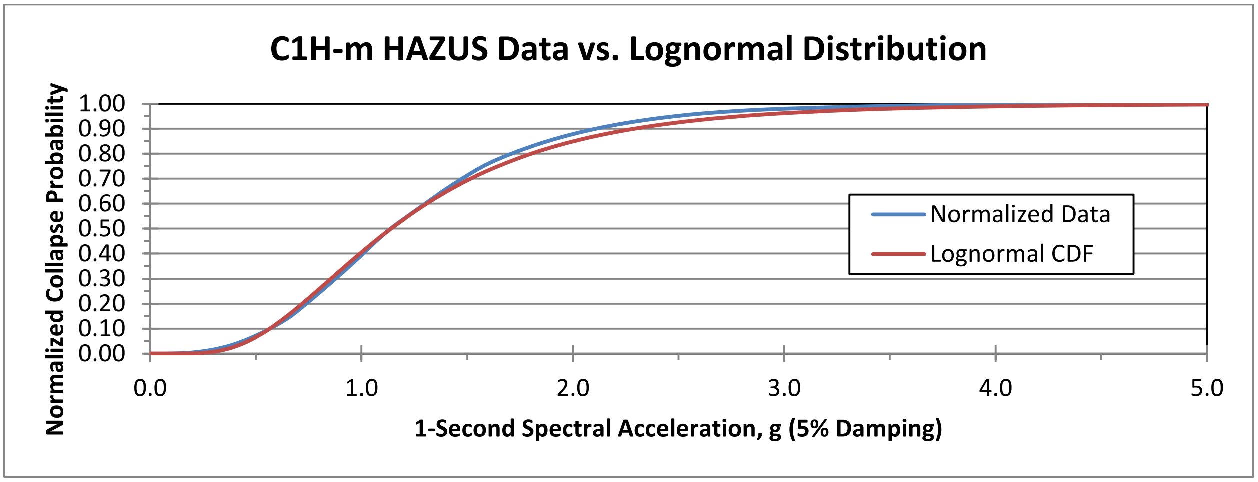

Figure 10. Fitted lognormal curve to data from highrise concrete moment frame building subjected to moderate code

Kolmogorov-Smirnov Goodness-of-Fit Test – Moderate Code

Table 9 presents the median collapse capacities, log-standard deviations, number of data points, critical K.S. statistics, and actual K.S. statistics for all moderate-code building types.

Table 9. Median collapse capacities, logarithmic standard deviations, number of data points, criticial K.S. statistics, and actual K.S. statistics for moderate code building types

CDF Data Comparisons						
Building Type	Median Collapse Capacity, Θ (g)	Log. Standard Deviation, β	# of Data Points, N	95% Critical Standard K.S. Statistic	95% Critical Adjusted K.S. Statistic	K.S. Statistic
W1-m	2.236	0.478	51	0.190	0.124	0.044
W2-m	1.929	0.490	51	0.190	0.124	0.015
S1L-m	1.269	0.498	49	0.194	0.127	0.023
S1M-m	1.269	0.540	43	0.207	0.135	0.041
S1H-m	1.216	0.580	41	0.212	0.138	0.059
S2L-m	1.309	0.504	51	0.190	0.124	0.012
S2M-m	1.509	0.531	45	0.203	0.132	0.031
S2H-m	1.577	0.579	42	0.210	0.137	0.065
S3-m	1.050	0.517	51	0.190	0.124	0.026
S4L-m	1.180	0.487	51	0.190	0.124	0.013
S4M-m	1.369	0.524	47	0.198	0.129	0.018
S4H-m	1.451	0.549	43	0.207	0.135	0.035
S5L-l	0.723	0.497	51	0.190	0.124	0.015
S5M-l	0.850	0.529	48	0.196	0.128	0.018
S5H-l	0.892	0.543	44	0.205	0.134	0.016
C1L-m	1.206	0.485	51	0.190	0.124	0.019
C1M-m	1.397	0.519	46	0.201	0.131	0.027
C1H-m	1.139	0.545	43	0.207	0.135	0.029
C2L-m	1.390	0.476	51	0.190	0.124	0.017
C2M-m	1.631	0.504	48	0.196	0.128	0.021
C2H-m	1.663	0.534	44	0.205	0.134	0.036
C3L-l	0.660	0.484	51	0.190	0.124	0.017
C3M-l	0.763	0.532	50	0.192	0.125	0.016
C3H-l	0.799	0.562	46	0.201	0.131	0.032
PC1-m	1.220	0.548	51	0.190	0.124	0.039
PC2L-m	1.168	0.474	51	0.190	0.124	0.016
PC2M-m	1.354	0.508	48	0.196	0.128	0.013
PC2H-m	1.401	0.532	45	0.203	0.132	0.031
RM1L-m	1.367	0.537	51	0.190	0.124	0.024
RM1M-m	1.593	0.505	49	0.194	0.127	0.019
RM2L-m	1.369	0.530	51	0.190	0.124	0.025
RM2M-m	1.593	0.501	49	0.194	0.127	0.020
RM2H-m	1.617	0.548	45	0.203	0.132	0.039
URML-l	0.759	0.572	51	0.190	0.124	0.016
URMM-l	0.709	0.491	51	0.190	0.124	0.013
Average	1.275	0.521	48	0.197	0.128	0.026

Further Data Collection – Moderate Code

Tables 10 and 11 provide the probabilities of collapse based on MCE design-level shaking and MCE_R design-level shaking, respectively (S_{D1}-values for MCE and MCE_R). These probabilities are signified by P_{MCE} and P_{MCER}, respectively. Table 12 shows the annual frequencies of collapse calculated via the risk integral, and represented by λ. Tables 13 - 15 show the resulting scores for each building type in each location calculated from P_{MCE}, P_{MCER}, and λ, respectively. Tables 16 and 17 provide the performance modification factors, represented by PMF and PMF', for each building type in each location. Finally, Tables 18 and 19 show the discrepancy values, signified by D and D', for each scenario.

Table 10. Probability of collapse given S_{D1}-level shaking in MCE high-seismicity locations

Probability of Collapse Given S_{D1}-Level Shaking in MCE High-Seismicity Locations (P_{MCE})																										
Building Type	Seattle 1	Seattle 2	Portland 1	Bay 1	Bay 2	Bay 3	Fresno 1	LA 1	LA 2	LA 3	LA 4	SD 1	SD 2	SLC 1	SLC 2	Evansville 1	Memphis 1	Memphis 2	Charleston 1	Charleston 2	Malone 1	San Juan 1	Anchorage 1		Mean Value	Standard Deviation
W1-m	0.00%	0.00%	0.00%	0.00%	0.01%	0.18%	0.00%	0.21%	0.02%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.27%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%		0.03%	0.08%
W2-m	0.00%	0.00%	0.00%	0.00%	0.03%	0.34%	0.00%	0.38%	0.06%	0.01%	0.00%	0.00%	0.00%	0.02%	0.00%	0.00%	0.48%	0.01%	0.04%	0.00%	0.00%	0.00%	0.00%		0.06%	0.14%
S1L-m	0.13%	0.00%	0.05%	0.15%	0.52%	2.92%	0.00%	3.10%	0.93%	0.18%	0.15%	0.02%	0.02%	0.39%	0.01%	0.01%	3.56%	0.20%	0.75%	0.08%	0.00%	0.04%	0.11%		0.58%	1.07%
S1M-m	0.12%	0.00%	0.05%	0.14%	0.41%	1.87%	0.01%	1.98%	0.68%	0.16%	0.14%	0.03%	0.02%	0.32%	0.01%	0.01%	2.24%	0.18%	0.56%	0.08%	0.00%	0.05%	0.10%		0.40%	0.67%
S1H-m	0.12%	0.00%	0.06%	0.13%	0.33%	1.24%	0.01%	1.29%	0.51%	0.15%	0.13%	0.03%	0.03%	0.27%	0.01%	0.01%	1.44%	0.16%	0.44%	0.08%	0.00%	0.05%	0.10%		0.29%	0.43%
S2L-m	0.12%	0.00%	0.04%	0.14%	0.48%	2.75%	0.00%	2.92%	0.86%	0.17%	0.14%	0.02%	0.02%	0.36%	0.01%	0.01%	3.36%	0.19%	0.69%	0.07%	0.00%	0.04%	0.10%		0.54%	1.01%
S2M-m	0.05%	0.00%	0.02%	0.06%	0.20%	1.29%	0.00%	1.38%	0.37%	0.07%	0.06%	0.01%	0.01%	0.15%	0.00%	0.00%	1.62%	0.08%	0.30%	0.03%	0.00%	0.02%	0.04%		0.25%	0.48%
S2H-m	0.04%	0.00%	0.02%	0.04%	0.14%	0.75%	0.00%	0.80%	0.24%	0.05%	0.05%	0.01%	0.01%	0.11%	0.00%	0.00%	0.93%	0.06%	0.20%	0.03%	0.00%	0.01%	0.03%		0.15%	0.28%
S3-m	0.13%	0.00%	0.06%	0.15%	0.41%	1.54%	0.01%	1.61%	0.65%	0.18%	0.15%	0.03%	0.03%	0.33%	0.01%	0.01%	1.77%	0.19%	0.55%	0.09%	0.00%	0.05%	0.12%		0.35%	0.54%
S4L-m	0.17%	0.00%	0.06%	0.19%	0.65%	3.36%	0.01%	3.55%	1.14%	0.23%	0.19%	0.03%	0.02%	0.49%	0.01%	0.01%	4.02%	0.26%	0.93%	0.10%	0.00%	0.05%	0.14%		0.68%	1.22%
S4M-m	0.07%	0.00%	0.03%	0.08%	0.28%	1.59%	0.00%	1.69%	0.50%	0.10%	0.08%	0.01%	0.01%	0.21%	0.00%	0.00%	1.95%	0.11%	0.41%	0.04%	0.00%	0.02%	0.06%		0.32%	0.58%
S4H-m	0.04%	0.00%	0.02%	0.05%	0.16%	0.87%	0.00%	0.92%	0.28%	0.06%	0.05%	0.01%	0.01%	0.12%	0.00%	0.00%	1.07%	0.07%	0.23%	0.03%	0.00%	0.02%	0.04%		0.17%	0.32%
S5L-l	1.24%	0.03%	0.66%	1.35%	2.80%	6.27%	0.13%	6.41%	3.80%	1.52%	1.35%	0.43%	0.34%	2.39%	0.15%	0.16%	6.71%	1.63%	3.40%	0.89%	0.03%	0.61%	1.11%		1.89%	2.09%
S5M-l	0.52%	0.01%	0.27%	0.57%	1.27%	3.34%	0.05%	3.43%	1.79%	0.65%	0.57%	0.17%	0.14%	1.06%	0.06%	0.06%	3.67%	0.70%	1.57%	0.37%	0.01%	0.25%	0.46%		0.91%	1.13%
S5H-l	0.28%	0.01%	0.15%	0.31%	0.69%	1.89%	0.03%	1.95%	0.98%	0.35%	0.31%	0.09%	0.08%	0.58%	0.03%	0.03%	2.09%	0.38%	0.86%	0.20%	0.01%	0.13%	0.25%		0.51%	0.64%
C1L-m	0.24%	0.00%	0.09%	0.27%	0.96%	5.22%	0.01%	5.53%	1.71%	0.33%	0.27%	0.04%	0.03%	0.72%	0.01%	0.01%	6.30%	0.37%	1.38%	0.14%	0.00%	0.08%	0.20%		1.04%	1.90%
C1M-m	0.13%	0.00%	0.05%	0.14%	0.51%	3.03%	0.00%	3.23%	0.92%	0.18%	0.14%	0.02%	0.02%	0.38%	0.01%	0.01%	3.75%	0.20%	0.74%	0.07%	0.00%	0.04%	0.10%		0.59%	1.12%
C1H-m	0.20%	0.00%	0.09%	0.22%	0.59%	2.26%	0.01%	2.37%	0.93%	0.26%	0.22%	0.05%	0.04%	0.47%	0.02%	0.02%	2.64%	0.28%	0.79%	0.13%	0.00%	0.08%	0.17%		0.52%	0.80%
C2L-m	0.10%	0.00%	0.03%	0.11%	0.50%	3.77%	0.00%	4.05%	0.98%	0.14%	0.12%	0.01%	0.01%	0.36%	0.00%	0.00%	4.78%	0.17%	0.76%	0.05%	0.00%	0.03%	0.08%		0.70%	1.42%
C2M-m	0.05%	0.00%	0.01%	0.05%	0.23%	2.01%	0.00%	2.18%	0.47%	0.07%	0.05%	0.01%	0.00%	0.17%	0.00%	0.00%	2.62%	0.08%	0.36%	0.02%	0.00%	0.01%	0.04%		0.37%	0.77%
C2H-m	0.03%	0.00%	0.01%	0.04%	0.14%	1.02%	0.00%	1.10%	0.26%	0.04%	0.04%	0.01%	0.00%	0.10%	0.00%	0.00%	1.31%	0.05%	0.21%	0.02%	0.00%	0.01%	0.03%		0.19%	0.39%
C3L-l	2.95%	0.09%	1.63%	3.19%	6.28%	12.61%	0.33%	12.82%	8.24%	3.58%	3.20%	1.06%	0.86%	5.44%	0.39%	0.40%	13.29%	3.82%	7.47%	2.17%	0.08%	1.50%	2.65%		4.09%	4.18%
C3M-l	1.91%	0.07%	1.06%	2.08%	4.20%	9.57%	0.23%	9.80%	5.67%	2.33%	2.08%	0.70%	0.57%	3.60%	0.27%	0.28%	10.33%	2.49%	5.08%	1.41%	0.06%	0.98%	1.72%		2.89%	3.18%
C3H-l	0.71%	0.03%	0.40%	0.76%	1.51%	3.49%	0.10%	3.58%	2.04%	0.85%	0.77%	0.27%	0.22%	1.30%	0.11%	0.11%	3.79%	0.91%	1.83%	0.53%	0.03%	0.37%	0.64%		1.06%	1.16%
PC1-m	0.46%	0.01%	0.20%	0.51%	1.45%	6.06%	0.03%	6.38%	2.34%	0.60%	0.51%	0.12%	0.09%	1.14%	0.03%	0.04%	7.17%	0.66%	1.95%	0.30%	0.01%	0.18%	0.39%		1.33%	2.16%
PC2L-m	0.29%	0.00%	0.10%	0.33%	1.19%	6.39%	0.01%	6.75%	2.11%	0.41%	0.33%	0.05%	0.04%	0.89%	0.01%	0.01%	7.67%	0.46%	1.71%	0.17%	0.00%	0.09%	0.24%		1.27%	2.32%
PC2M-m	0.17%	0.00%	0.06%	0.19%	0.70%	4.16%	0.01%	4.43%	1.26%	0.24%	0.19%	0.03%	0.02%	0.52%	0.01%	0.01%	5.14%	0.27%	1.01%	0.10%	0.00%	0.05%	0.14%		0.81%	1.53%
PC2H-m	0.14%	0.00%	0.06%	0.16%	0.55%	3.05%	0.01%	3.25%	0.96%	0.20%	0.16%	0.03%	0.02%	0.42%	0.01%	0.01%	3.76%	0.22%	0.78%	0.09%	0.00%	0.05%	0.12%		0.61%	1.12%
RM1L-m	0.22%	0.00%	0.09%	0.25%	0.80%	4.20%	0.01%	4.45%	1.38%	0.30%	0.25%	0.05%	0.04%	0.61%	0.01%	0.01%	5.12%	0.33%	1.13%	0.13%	0.00%	0.08%	0.18%		0.85%	1.53%
RM1M-m	0.05%	0.00%	0.02%	0.06%	0.26%	2.14%	0.00%	2.32%	0.52%	0.08%	0.06%	0.01%	0.01%	0.19%	0.00%	0.00%	2.78%	0.09%	0.40%	0.03%	0.00%	0.01%	0.04%		0.39%	0.82%
RM2L-m	0.20%	0.00%	0.08%	0.23%	0.77%	4.16%	0.01%	4.42%	1.34%	0.28%	0.23%	0.04%	0.03%	0.58%	0.01%	0.01%	5.09%	0.31%	1.09%	0.12%	0.00%	0.07%	0.17%		0.84%	1.52%
RM2M-m	0.05%	0.00%	0.02%	0.06%	0.25%	2.12%	0.00%	2.30%	0.50%	0.07%	0.06%	0.01%	0.01%	0.18%	0.00%	0.00%	2.76%	0.08%	0.39%	0.03%	0.00%	0.01%	0.04%		0.39%	0.81%
RM2H-m	0.04%	0.00%	0.02%	0.05%	0.17%	1.12%	0.00%	1.21%	0.32%	0.06%	0.05%	0.01%	0.01%	0.13%	0.00%	0.00%	1.42%	0.07%	0.25%	0.03%	0.00%	0.01%	0.04%		0.22%	0.42%
URML-l	2.51%	0.14%	1.48%	2.69%	5.08%	10.88%	0.38%	11.13%	6.67%	2.99%	2.70%	1.03%	0.86%	4.42%	0.44%	0.45%	11.72%	3.17%	6.04%	1.91%	0.12%	1.38%	2.28%		3.50%	3.56%
URMM-l	2.43%	0.07%	1.30%	2.64%	5.47%	11.97%	0.25%	12.22%	7.36%	2.99%	2.65%	0.84%	0.67%	4.67%	0.30%	0.30%	12.77%	3.20%	6.61%	1.76%	0.06%	1.19%	2.18%		3.65%	3.99%
Mean	0.45%	0.01%	0.24%	0.50%	1.14%	3.70%	0.05%	3.86%	1.68%	0.57%	0.50%	0.15%	0.12%	0.95%	0.06%	0.06%	4.27%	0.61%	1.45%	0.32%	0.01%	0.22%	0.40%		0.93%	
Std. Dev.	0.77%	0.03%	0.44%	0.84%	1.61%	3.21%	0.10%	3.27%	2.10%	0.93%	0.84%	0.29%	0.24%	1.40%	0.11%	0.12%	3.41%	0.99%	1.91%	0.58%	0.03%	0.40%	0.70%			1.92%

Table 11. Probability of collapse given S_{D1}-level shaking in MCE_R high-seismicity locations

Probability of Collapse Given S_{D1}-Level Shaking in MCE_R High-Seismicity Locations (P_{MCER})																											
Building Type	PNW1	PNW2	PNW3	NorCal 1	NorCal2	NorCal3	SoCal1	SoCal2	SoCal3	SoCal4	SoCal5	SoCal6	SoCal7	Utah1	Utah2	NMad1	NMad2	NMad3	SC1	SC2	NY1	PR1	AK1		Mean Value	Standard Deviation
W1-m	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.14%	0.03%	0.00%	0.01%	0.01%	0.00%	0.00%	0.01%	0.00%	0.00%	0.22%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%		0.03%	0.06%
W2-m	0.01%	0.00%	0.00%	0.01%	0.01%	0.36%	0.28%	0.07%	0.00%	0.03%	0.02%	0.00%	0.00%	0.02%	0.00%	0.00%	0.39%	0.01%	0.05%	0.00%	0.00%	0.00%	0.01%		0.06%	0.12%
S1L-m	0.27%	0.00%	0.08%	0.29%	0.31%	3.00%	2.58%	1.09%	0.02%	0.63%	0.42%	0.10%	0.07%	0.44%	0.01%	0.01%	3.17%	0.22%	0.80%	0.09%	0.00%	0.10%	0.18%		0.60%	0.96%
S1M-m	0.23%	0.00%	0.08%	0.25%	0.25%	1.92%	1.68%	0.78%	0.03%	0.48%	0.34%	0.09%	0.07%	0.35%	0.01%	0.01%	2.02%	0.19%	0.59%	0.09%	0.00%	0.10%	0.16%		0.42%	0.61%
S1H-m	0.20%	0.01%	0.08%	0.21%	0.22%	1.26%	1.12%	0.58%	0.03%	0.38%	0.28%	0.09%	0.07%	0.29%	0.02%	0.02%	1.32%	0.17%	0.45%	0.09%	0.00%	0.10%	0.15%		0.31%	0.40%
S2L-m	0.25%	0.00%	0.07%	0.27%	0.28%	2.82%	2.42%	1.01%	0.02%	0.57%	0.39%	0.09%	0.06%	0.40%	0.01%	0.01%	2.99%	0.20%	0.73%	0.08%	0.00%	0.09%	0.16%		0.56%	0.90%
S2M-m	0.10%	0.00%	0.03%	0.11%	0.12%	1.33%	1.12%	0.44%	0.01%	0.24%	0.16%	0.04%	0.03%	0.17%	0.00%	0.00%	1.42%	0.08%	0.31%	0.03%	0.00%	0.04%	0.07%		0.25%	0.43%
S2H-m	0.08%	0.00%	0.02%	0.08%	0.09%	0.77%	0.66%	0.28%	0.01%	0.17%	0.12%	0.03%	0.02%	0.12%	0.00%	0.00%	0.82%	0.06%	0.21%	0.03%	0.00%	0.03%	0.05%		0.16%	0.25%
S3-m	0.24%	0.01%	0.09%	0.26%	0.27%	1.57%	1.41%	0.73%	0.03%	0.48%	0.35%	0.11%	0.08%	0.36%	0.02%	0.01%	1.63%	0.21%	0.58%	0.10%	0.00%	0.11%	0.17%		0.38%	0.50%
S4L-m	0.34%	0.00%	0.10%	0.37%	0.39%	3.44%	2.99%	1.32%	0.03%	0.78%	0.53%	0.12%	0.09%	0.55%	0.02%	0.01%	3.62%	0.28%	0.98%	0.11%	0.00%	0.13%	0.23%		0.71%	1.10%
S4M-m	0.15%	0.00%	0.04%	0.16%	0.17%	1.63%	1.40%	0.59%	0.01%	0.34%	0.23%	0.05%	0.04%	0.24%	0.01%	0.01%	1.73%	0.12%	0.43%	0.05%	0.00%	0.06%	0.10%		0.33%	0.52%
S4H-m	0.09%	0.00%	0.03%	0.09%	0.10%	0.89%	0.76%	0.32%	0.01%	0.19%	0.13%	0.03%	0.02%	0.14%	0.00%	0.00%	0.94%	0.07%	0.24%	0.03%	0.00%	0.03%	0.06%		0.18%	0.28%
S5L-l	1.93%	0.10%	0.88%	2.03%	2.07%	6.33%	5.99%	4.10%	0.42%	3.09%	2.50%	1.03%	0.83%	2.55%	0.25%	0.21%	6.46%	1.71%	3.50%	0.97%	0.05%	1.06%	1.50%		2.15%	1.96%
S5M-l	0.84%	0.04%	0.36%	0.88%	0.90%	3.38%	3.13%	1.96%	0.17%	1.41%	1.11%	0.43%	0.34%	1.14%	0.10%	0.08%	3.47%	0.74%	1.63%	0.40%	0.02%	0.44%	0.64%		1.03%	1.05%
S5H-l	0.46%	0.02%	0.20%	0.48%	0.49%	1.92%	1.77%	1.08%	0.09%	0.77%	0.61%	0.23%	0.19%	0.62%	0.06%	0.05%	1.97%	0.40%	0.89%	0.22%	0.01%	0.24%	0.35%		0.57%	0.59%
C1L-m	0.50%	0.01%	0.14%	0.54%	0.56%	5.36%	4.64%	2.00%	0.04%	1.15%	0.78%	0.18%	0.13%	0.81%	0.02%	0.02%	5.65%	0.41%	1.46%	0.16%	0.00%	0.19%	0.32%		1.09%	1.72%
C1M-m	0.26%	0.00%	0.07%	0.28%	0.30%	3.12%	2.65%	1.08%	0.02%	0.61%	0.41%	0.09%	0.07%	0.43%	0.01%	0.01%	3.31%	0.21%	0.78%	0.09%	0.00%	0.10%	0.17%		0.61%	1.00%
C1H-m	0.35%	0.01%	0.13%	0.38%	0.39%	2.31%	2.06%	1.05%	0.05%	0.68%	0.50%	0.16%	0.12%	0.52%	0.03%	0.02%	2.41%	0.30%	0.82%	0.14%	0.00%	0.16%	0.25%		0.56%	0.73%
C2L-m	0.23%	0.00%	0.05%	0.25%	0.26%	3.90%	3.25%	1.17%	0.01%	0.61%	0.39%	0.07%	0.05%	0.41%	0.01%	0.00%	4.16%	0.18%	0.81%	0.06%	0.00%	0.07%	0.14%		0.70%	1.26%
C2M-m	0.11%	0.00%	0.02%	0.12%	0.12%	2.08%	1.70%	0.57%	0.01%	0.29%	0.18%	0.03%	0.02%	0.19%	0.00%	0.00%	2.24%	0.08%	0.39%	0.03%	0.00%	0.03%	0.06%		0.36%	0.67%
C2H-m	0.07%	0.00%	0.02%	0.07%	0.08%	1.05%	0.87%	0.32%	0.01%	0.17%	0.11%	0.02%	0.02%	0.11%	0.00%	0.00%	1.13%	0.05%	0.22%	0.02%	0.00%	0.02%	0.04%		0.19%	0.34%
C3L-l	4.46%	0.25%	2.13%	4.66%	4.76%	12.70%	12.15%	8.81%	1.04%	6.85%	5.65%	2.48%	2.02%	5.77%	0.64%	0.53%	12.90%	4.00%	7.67%	2.34%	0.14%	2.56%	3.52%		4.70%	3.92%
C3M-l	2.92%	0.18%	1.39%	3.06%	3.13%	9.68%	9.10%	6.13%	0.69%	4.62%	3.75%	1.61%	1.32%	3.83%	0.43%	0.36%	9.89%	2.61%	5.23%	1.52%	0.10%	1.66%	2.29%		3.28%	2.96%
C3H-l	1.06%	0.08%	0.52%	1.11%	1.13%	3.53%	3.30%	2.20%	0.27%	1.66%	1.35%	0.60%	0.49%	1.38%	0.17%	0.14%	3.61%	0.95%	1.88%	0.57%	0.04%	0.62%	0.84%		1.20%	1.07%
PC1-m	0.84%	0.02%	0.29%	0.90%	0.92%	6.20%	5.46%	2.66%	0.11%	1.68%	1.21%	0.36%	0.27%	1.26%	0.06%	0.05%	6.50%	0.71%	2.05%	0.33%	0.01%	0.37%	0.59%		1.43%	1.96%
PC2L-m	0.61%	0.01%	0.16%	0.66%	0.69%	6.55%	5.68%	2.47%	0.05%	1.42%	0.96%	0.21%	0.15%	1.00%	0.02%	0.02%	6.90%	0.49%	1.80%	0.19%	0.00%	0.22%	0.39%		1.33%	2.10%
PC2M-m	0.35%	0.00%	0.10%	0.39%	0.40%	4.28%	3.65%	1.48%	0.03%	0.84%	0.56%	0.12%	0.09%	0.58%	0.01%	0.01%	4.54%	0.29%	1.07%	0.11%	0.00%	0.13%	0.23%		0.84%	1.37%
PC2H-m	0.29%	0.00%	0.08%	0.31%	0.32%	3.14%	2.69%	1.13%	0.03%	0.65%	0.45%	0.11%	0.08%	0.46%	0.01%	0.01%	3.33%	0.24%	0.83%	0.10%	0.00%	0.11%	0.19%		0.63%	1.00%
RM1L-m	0.43%	0.01%	0.13%	0.47%	0.48%	4.31%	3.71%	1.61%	0.05%	0.95%	0.66%	0.17%	0.12%	0.68%	0.02%	0.02%	4.56%	0.36%	1.19%	0.15%	0.00%	0.17%	0.29%		0.89%	1.37%
RM1M-m	0.12%	0.00%	0.03%	0.13%	0.14%	2.22%	1.83%	0.63%	0.01%	0.32%	0.20%	0.04%	0.03%	0.21%	0.00%	0.00%	2.39%	0.10%	0.43%	0.03%	0.00%	0.04%	0.07%		0.39%	0.72%
RM2L-m	0.41%	0.01%	0.12%	0.44%	0.46%	4.28%	3.67%	1.56%	0.04%	0.91%	0.63%	0.15%	0.11%	0.65%	0.02%	0.02%	4.53%	0.34%	1.15%	0.14%	0.00%	0.16%	0.27%		0.87%	1.37%
RM2M-m	0.11%	0.00%	0.03%	0.13%	0.13%	2.20%	1.81%	0.61%	0.01%	0.31%	0.20%	0.03%	0.02%	0.21%	0.00%	0.00%	2.37%	0.09%	0.42%	0.03%	0.00%	0.04%	0.07%		0.38%	0.71%
RM2H-m	0.09%	0.00%	0.02%	0.10%	0.10%	1.16%	0.97%	0.38%	0.01%	0.21%	0.14%	0.03%	0.02%	0.15%	0.00%	0.00%	1.24%	0.07%	0.27%	0.03%	0.00%	0.03%	0.06%		0.22%	0.37%
URML-l	3.66%	0.31%	1.88%	3.82%	3.89%	11.00%	10.36%	7.16%	1.01%	5.53%	4.58%	2.14%	1.80%	4.67%	0.67%	0.57%	11.23%	3.31%	6.20%	2.04%	0.19%	2.21%	2.94%		3.96%	3.31%
URMM-l	3.77%	0.19%	1.73%	3.96%	4.05%	12.09%	11.46%	7.94%	0.82%	6.01%	4.87%	2.02%	1.64%	4.98%	0.50%	0.40%	12.31%	3.36%	6.80%	1.91%	0.10%	2.09%	2.93%		4.17%	3.74%
Mean	0.74%	0.04%	0.32%	0.78%	0.80%	3.77%	3.38%	1.87%	0.15%	1.29%	0.99%	0.37%	0.30%	1.02%	0.09%	0.07%	3.93%	0.65%	1.51%	0.35%	0.02%	0.39%	0.56%		1.02%	
Std. Dev.	1.16%	0.08%	0.57%	1.21%	1.23%	3.24%	3.09%	2.24%	0.29%	1.75%	1.45%	0.65%	0.54%	1.48%	0.18%	0.15%	3.29%	1.04%	1.96%	0.62%	0.04%	0.67%	0.92%			1.91%

Table 12. Annual frequency of collapse in high-seismicity locations

	Annual Frequency of Collapse (λ)																									
Building Type	PNW1	PNW2	PNW3	NorCal 1	NorCal2	NorCal3	SoCal1	SoCal2	SoCal3	SoCal4	SoCal5	SoCal6	SoCal7	Utah1	Utah2	NMad1	NMad2	NMad3	SC1	SC2	NY1	PR1	AK1		Mean Value	Standard Deviation
W1-m	1.1E-06	5.2E-08	4.9E-07	6.1E-07	2.6E-06	9.8E-06	1.1E-05	3.3E-06	3.6E-08	1.0E-06	9.1E-07	1.2E-07	9.3E-08	2.5E-06	4.2E-08	1.4E-07	9.4E-06	1.6E-06	4.1E-06	1.2E-06	1.5E-07	1.6E-07	2.7E-08		2.2E-06	3.3E-06
W2-m	1.7E-06	9.9E-08	8.2E-07	1.3E-06	4.4E-06	1.4E-05	1.6E-05	5.1E-06	7.9E-08	1.8E-06	1.6E-06	2.7E-07	2.1E-07	3.5E-06	8.1E-08	2.4E-07	1.2E-05	2.4E-06	5.3E-06	1.7E-06	2.3E-07	3.6E-07	6.2E-08		3.2E-06	4.6E-06
S1L-m	1.4E-05	1.2E-06	7.4E-06	1.9E-05	4.4E-05	8.6E-05	1.0E-04	3.9E-05	1.5E-06	2.0E-05	1.9E-05	4.6E-06	3.8E-06	2.1E-05	9.7E-07	2.5E-06	5.9E-05	1.7E-05	2.7E-05	1.1E-05	1.8E-06	6.2E-06	1.1E-06		2.2E-05	2.8E-05
S1M-m	1.0E-05	9.2E-07	5.3E-06	1.5E-05	3.2E-05	5.7E-05	6.8E-05	2.6E-05	1.4E-06	1.5E-05	1.5E-05	3.9E-06	3.4E-06	1.4E-05	7.3E-07	1.9E-06	3.7E-05	1.1E-05	1.8E-05	7.4E-06	1.2E-06	5.2E-06	8.9E-07		1.5E-05	1.8E-05
S1H-m	7.6E-06	7.6E-07	4.1E-06	1.3E-05	2.5E-05	3.9E-05	4.7E-05	1.9E-05	1.4E-06	1.2E-05	1.3E-05	3.6E-06	3.2E-06	9.5E-06	5.9E-07	1.5E-06	2.4E-05	7.8E-06	1.1E-05	5.1E-06	9.4E-07	4.7E-06	8.1E-07		1.1E-05	1.2E-05
S2L-m	1.3E-05	1.1E-06	7.0E-06	1.8E-05	4.1E-05	8.2E-05	9.8E-05	3.7E-05	1.4E-06	1.9E-05	1.8E-05	4.2E-06	3.5E-06	2.0E-05	9.0E-07	2.3E-06	5.7E-05	1.6E-05	2.6E-05	1.0E-05	1.7E-06	5.7E-06	9.8E-07		2.1E-05	2.6E-05
S2M-m	6.3E-06	5.0E-07	3.2E-06	7.8E-06	1.9E-05	4.1E-05	4.8E-05	1.8E-05	6.1E-07	8.4E-06	7.9E-06	1.8E-06	1.5E-06	1.0E-05	4.0E-07	1.1E-06	3.0E-05	7.6E-06	1.4E-05	5.2E-06	7.9E-07	2.5E-06	4.3E-07		1.0E-05	1.3E-05
S2H-m	4.0E-06	3.4E-07	2.1E-06	5.5E-06	1.2E-05	2.4E-05	2.9E-05	1.1E-05	4.9E-07	5.6E-06	5.4E-06	1.3E-06	1.2E-06	6.0E-06	2.7E-07	7.0E-07	1.7E-05	4.6E-06	8.0E-06	3.1E-06	5.0E-07	1.8E-06	3.1E-07		6.3E-06	7.8E-06
S3-m	9.0E-06	8.9E-07	4.9E-06	1.5E-05	2.9E-05	4.6E-05	5.5E-05	2.3E-05	1.5E-06	1.5E-05	1.5E-05	4.0E-06	3.6E-06	1.1E-05	7.0E-07	1.8E-06	2.8E-05	9.3E-06	1.3E-05	6.1E-06	1.1E-06	5.4E-06	9.2E-07		1.3E-05	1.5E-05
S4L-m	1.7E-05	1.4E-06	8.7E-06	2.4E-05	5.2E-05	9.7E-05	1.2E-04	4.5E-05	1.9E-06	2.4E-05	2.3E-05	5.6E-06	4.7E-06	2.4E-05	1.2E-06	3.0E-06	6.4E-05	1.9E-05	3.0E-05	1.2E-05	2.0E-06	7.6E-06	1.3E-06		2.5E-05	3.1E-05
S4M-m	7.9E-06	6.6E-07	4.1E-06	1.1E-05	2.4E-05	4.9E-05	5.8E-05	2.2E-05	8.7E-07	1.1E-05	1.1E-05	2.5E-06	2.2E-06	1.2E-05	5.3E-07	1.4E-06	3.4E-05	9.2E-06	1.6E-05	6.2E-06	9.8E-07	3.4E-06	6.0E-07		1.2E-05	1.5E-05
S4H-m	4.4E-06	3.7E-07	2.3E-06	6.1E-06	1.4E-05	2.7E-05	3.2E-05	1.2E-05	5.2E-07	6.3E-06	6.0E-06	1.5E-06	1.3E-06	6.7E-06	3.0E-07	7.8E-07	1.9E-05	5.2E-06	8.8E-06	3.5E-06	5.6E-07	2.0E-06	3.4E-07		7.0E-06	8.7E-06
S5L-l	5.5E-05	6.5E-06	3.0E-05	1.2E-04	1.9E-04	2.2E-04	2.6E-04	1.2E-04	1.5E-05	1.0E-04	1.1E-04	3.5E-05	3.3E-05	5.2E-05	4.9E-06	1.3E-05	1.0E-04	4.7E-05	5.5E-05	3.0E-05	6.8E-06	4.5E-05	7.8E-06		7.2E-05	7.1E-05
S5M-l	2.6E-05	2.9E-06	1.4E-05	5.2E-05	8.7E-05	1.1E-04	1.3E-04	5.8E-05	6.5E-06	4.7E-05	4.9E-05	1.5E-05	1.4E-05	2.6E-05	2.2E-06	5.7E-06	5.7E-05	2.3E-05	2.9E-05	1.5E-05	3.2E-06	2.0E-05	3.4E-06		3.5E-05	3.5E-05
S5H-l	1.4E-05	1.6E-06	7.8E-06	2.9E-05	4.8E-05	6.2E-05	7.4E-05	3.2E-05	3.6E-06	2.6E-05	2.7E-05	8.3E-06	7.8E-06	1.5E-05	1.2E-06	3.1E-06	3.3E-05	1.3E-05	1.7E-05	8.4E-06	1.8E-06	1.1E-05	1.9E-06		1.9E-05	2.0E-05
C1L-m	2.5E-05	2.2E-06	1.3E-05	3.5E-05	7.8E-05	1.5E-04	1.8E-04	6.9E-05	2.8E-06	3.6E-05	3.4E-05	8.2E-06	6.9E-06	3.7E-05	1.7E-06	4.4E-06	1.0E-04	2.9E-05	4.7E-05	1.9E-05	3.1E-06	1.1E-05	1.9E-06		3.9E-05	4.8E-05
C1M-m	1.5E-05	1.2E-06	7.7E-06	1.9E-05	4.5E-05	9.3E-05	1.1E-04	4.1E-05	1.5E-06	2.0E-05	1.9E-05	4.5E-06	3.8E-06	2.3E-05	9.7E-07	2.5E-06	6.6E-05	1.8E-05	3.0E-05	1.2E-05	1.8E-06	6.1E-06	1.1E-06		2.4E-05	3.0E-05
C1H-m	1.3E-05	1.3E-06	7.2E-06	2.3E-05	4.3E-05	6.9E-05	8.3E-05	3.3E-05	2.3E-06	2.1E-05	2.2E-05	6.0E-06	5.3E-06	1.7E-05	1.0E-06	2.6E-06	4.2E-05	1.4E-05	2.0E-05	9.1E-06	1.7E-06	7.9E-06	1.4E-06		1.9E-05	2.2E-05
C2L-m	1.7E-05	1.3E-06	8.7E-06	1.9E-05	5.0E-05	1.1E-04	1.4E-04	4.9E-05	1.3E-06	2.2E-05	2.0E-05	4.3E-06	3.4E-06	2.8E-05	1.0E-06	2.7E-06	8.5E-05	2.1E-05	3.8E-05	1.4E-05	2.1E-06	5.8E-06	1.0E-06		2.8E-05	3.7E-05
C2M-m	9.5E-06	6.6E-07	4.7E-06	9.6E-06	2.7E-05	6.8E-05	7.9E-05	2.7E-05	6.6E-07	1.1E-05	1.0E-05	2.1E-06	1.7E-06	1.7E-05	5.4E-07	1.4E-06	5.3E-05	1.2E-05	2.4E-05	8.4E-06	1.2E-06	2.9E-06	5.0E-07		1.6E-05	2.2E-05
C2H-m	5.0E-06	3.7E-07	2.5E-06	5.5E-06	1.4E-05	3.4E-05	4.0E-05	1.4E-05	4.1E-07	6.3E-06	5.8E-06	1.3E-06	1.0E-06	8.5E-06	3.0E-07	7.9E-07	2.6E-05	6.2E-06	1.2E-05	4.3E-06	6.3E-07	1.7E-06	3.0E-07		8.3E-06	1.1E-05
C3L-l	1.2E-04	1.5E-05	6.8E-05	2.8E-04	4.2E-04	4.6E-04	5.6E-04	2.6E-04	3.7E-05	2.4E-04	2.6E-04	8.4E-05	8.0E-05	1.1E-04	1.1E-05	2.9E-05	2.1E-04	1.0E-04	1.1E-04	6.5E-05	1.5E-05	1.1E-04	1.9E-05		1.6E-04	1.5E-04
C3M-l	8.7E-05	1.0E-05	4.7E-05	1.9E-04	2.9E-04	3.4E-04	4.1E-04	1.8E-04	2.6E-05	1.6E-04	1.8E-04	5.7E-05	5.4E-05	8.1E-05	7.7E-06	2.0E-05	1.6E-04	7.2E-05	8.6E-05	4.7E-05	1.1E-05	7.3E-05	1.3E-05		1.1E-04	1.1E-04
C3H-l	3.2E-05	3.9E-06	1.7E-05	7.0E-05	1.1E-04	1.2E-04	1.5E-04	6.8E-05	1.0E-05	6.2E-05	6.7E-05	2.2E-05	2.1E-05	3.0E-05	2.9E-06	7.4E-06	6.0E-05	2.7E-05	3.2E-05	1.7E-05	4.0E-06	2.8E-05	4.9E-06		4.2E-05	4.1E-05
PC1-m	3.4E-05	3.2E-06	1.8E-05	5.5E-05	1.1E-04	1.8E-04	2.2E-04	8.7E-05	5.4E-06	5.3E-05	5.3E-05	1.4E-05	1.3E-05	4.5E-05	2.5E-06	6.5E-06	1.2E-04	3.7E-05	5.6E-05	2.4E-05	4.2E-06	1.9E-05	3.3E-06		5.1E-05	5.9E-05
PC2L-m	3.1E-05	2.6E-06	1.6E-05	4.3E-05	9.5E-05	1.8E-04	2.2E-04	8.3E-05	3.3E-06	4.4E-05	4.1E-05	1.0E-05	8.4E-06	4.5E-05	2.1E-06	5.4E-06	1.2E-04	3.5E-05	5.6E-05	2.3E-05	3.8E-06	1.4E-05	2.4E-06		4.7E-05	5.8E-05
PC2M-m	2.0E-05	1.6E-06	1.0E-05	2.6E-05	6.1E-05	1.3E-04	1.5E-04	5.5E-05	2.0E-06	2.8E-05	2.6E-05	6.1E-06	5.1E-06	3.1E-05	1.3E-06	3.4E-06	8.9E-05	2.4E-05	4.1E-05	1.6E-05	2.5E-06	8.3E-06	1.4E-06		3.2E-05	4.0E-05
PC2H-m	1.5E-05	1.3E-06	8.0E-06	2.1E-05	4.7E-05	9.4E-05	1.1E-04	4.2E-05	1.7E-06	2.2E-05	2.0E-05	5.0E-06	4.2E-06	2.3E-05	1.0E-06	2.7E-06	6.6E-05	1.8E-05	3.0E-05	1.2E-05	1.9E-06	6.7E-06	1.2E-06		2.4E-05	3.0E-05
RM1L-m	2.2E-05	1.8E-06	1.1E-05	3.0E-05	6.6E-05	1.3E-04	1.5E-04	5.8E-05	2.6E-06	3.1E-05	3.0E-05	7.3E-06	6.3E-06	3.2E-05	1.5E-06	3.8E-06	8.9E-05	2.5E-05	4.1E-05	1.6E-05	2.7E-06	9.9E-06	1.7E-06		3.3E-05	4.1E-05
RM1M-m	1.0E-05	7.2E-07	5.1E-06	1.1E-05	2.9E-05	7.1E-05	8.3E-05	2.9E-05	7.4E-07	1.2E-05	1.1E-05	2.3E-06	1.9E-06	1.8E-05	5.9E-07	1.6E-06	5.5E-05	1.3E-05	2.4E-05	8.8E-06	1.3E-06	3.2E-06	5.6E-07		1.7E-05	2.3E-05
RM2L-m	2.1E-05	1.8E-06	1.1E-05	2.9E-05	6.4E-05	1.3E-04	1.5E-04	5.7E-05	2.4E-06	3.0E-05	2.8E-05	6.9E-06	5.9E-06	3.1E-05	1.4E-06	3.7E-06	8.8E-05	2.4E-05	4.1E-05	1.6E-05	2.6E-06	9.4E-06	1.6E-06		3.3E-05	4.1E-05
RM2M-m	9.9E-06	7.0E-07	5.0E-06	1.0E-05	2.8E-05	7.0E-05	8.3E-05	2.9E-05	7.0E-07	1.2E-05	1.1E-05	2.3E-06	1.8E-06	1.7E-05	5.7E-07	1.5E-06	5.5E-05	1.3E-05	2.4E-05	8.8E-06	1.3E-06	3.1E-06	5.4E-07		1.7E-05	2.3E-05
RM2H-m	5.6E-06	4.4E-07	2.9E-06	6.8E-06	1.6E-05	3.7E-05	4.3E-05	1.6E-05	5.4E-07	7.4E-06	7.0E-06	1.6E-06	1.3E-06	9.1E-06	3.5E-07	9.3E-07	2.8E-05	6.8E-06	1.2E-05	4.6E-06	7.1E-07	2.2E-06	3.7E-07		9.2E-06	1.2E-05
URML-l	1.1E-04	1.4E-05	6.0E-05	2.5E-04	3.8E-04	4.1E-04	4.9E-04	2.3E-04	3.8E-05	2.2E-04	2.4E-04	8.1E-05	7.9E-05	9.8E-05	1.0E-05	2.6E-05	1.9E-04	8.7E-05	1.0E-04	5.6E-05	1.4E-05	1.0E-04	1.8E-05		1.4E-04	1.4E-04
URMM-l	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00		0.0E+00	0.0E+00
Mean	2.3E-05	2.4E-06	1.2E-05	4.2E-05	7.4E-05	1.1E-04	1.3E-04	5.4E-05	5.1E-06	3.9E-05	4.0E-05	1.2E-05	1.1E-05	2.7E-05	1.8E-06	4.7E-06	6.5E-05	2.2E-05	3.2E-05	1.5E-05	2.8E-06	1.5E-05	2.7E-06		3.2E-05	
Std. Dev.	2.9E-05	3.6E-06	1.6E-05	6.6E-05	9.9E-05	1.1E-04	1.3E-04	5.9E-05	9.6E-06	5.7E-05	6.3E-05	2.1E-05	2.0E-05	2.5E-05	2.6E-06	6.8E-06	4.9E-05	2.3E-05	2.6E-05	1.5E-05	3.6E-06	2.6E-05	4.6E-06			6.1E-05

Table 13. Score given S_{D1}-level shaking in MCE high-seismicity locations

Score Based on S_{D1}-Level Shaking in MCE Locations (S)																										
Building Type	PNW1	PNW2	PNW3	NorCal 1	NorCal2	NorCal3	SoCal1	SoCal2	SoCal3	SoCal4	SoCal5	SoCal6	SoCal7	Utah1	Utah2	NMad1	NMad2	NMad3	SC1	SC2	NY1	PR1	AK1		Mean Value	Standard Deviation
W1-m	5.02	8.26	5.67	4.93	4.06	2.74	2.68	3.64	7.18	4.79	4.93	6.09	6.30	4.26	7.03	7.01	2.56	4.72	3.80	5.36	8.39	5.75	5.14		5.23	1.64
W2-m	4.44	7.32	5.01	4.36	3.60	2.47	2.42	3.23	6.36	4.24	4.35	5.38	5.56	3.77	6.22	6.20	2.32	4.17	3.37	4.74	7.43	5.08	4.54		4.63	1.44
S1L-m	2.89	5.14	3.31	2.83	2.28	1.53	1.51	2.03	4.36	2.74	2.83	3.60	3.74	2.40	4.26	4.24	1.45	2.69	2.12	3.11	5.22	3.37	2.97		3.07	1.07
S1M-m	2.92	4.86	3.29	2.87	2.39	1.73	1.70	2.17	4.20	2.79	2.86	3.54	3.66	2.50	4.10	4.09	1.65	2.75	2.25	3.11	4.94	3.34	2.99		3.07	0.93
S1H-m	2.94	4.60	3.25	2.89	2.48	1.91	1.89	2.29	4.03	2.82	2.89	3.47	3.57	2.57	3.95	3.94	1.84	2.79	2.36	3.10	4.67	3.30	2.99		3.07	0.80
S2L-m	2.93	5.17	3.36	2.87	2.32	1.56	1.53	2.07	4.40	2.78	2.87	3.65	3.79	2.44	4.30	4.28	1.47	2.73	2.16	3.16	5.26	3.41	3.01		3.11	1.07
S2M-m	3.31	5.51	3.74	3.25	2.69	1.89	1.86	2.43	4.77	3.16	3.25	4.02	4.16	2.82	4.66	4.64	1.79	3.11	2.53	3.54	5.60	3.80	3.39		3.48	1.07
S2H-m	3.40	5.32	3.77	3.35	2.85	2.12	2.10	2.62	4.67	3.27	3.34	4.02	4.15	2.97	4.58	4.57	2.03	3.22	2.71	3.60	5.39	3.82	3.47		3.54	0.95
S3-m	2.87	4.75	3.22	2.82	2.38	1.81	1.79	2.19	4.09	2.75	2.82	3.46	3.58	2.48	4.00	3.99	1.75	2.71	2.26	3.05	4.82	3.27	2.93		3.03	0.87
S4L-m	2.78	5.03	3.20	2.72	2.19	1.47	1.45	1.94	4.25	2.64	2.72	3.49	3.63	2.31	4.14	4.12	1.40	2.59	2.03	3.00	5.11	3.26	2.86		2.97	1.05
S4M-m	3.14	5.28	3.55	3.08	2.55	1.80	1.77	2.30	4.55	2.99	3.08	3.83	3.96	2.67	4.45	4.43	1.71	2.95	2.39	3.35	5.36	3.60	3.21		3.30	1.03
S4H-m	3.37	5.39	3.76	3.31	2.80	2.06	2.04	2.56	4.70	3.23	3.31	4.02	4.15	2.91	4.61	4.59	1.97	3.18	2.65	3.57	5.47	3.81	3.44		3.52	0.99
S5L-l	1.91	3.46	2.18	1.87	1.55	1.20	1.19	1.42	2.90	1.82	1.87	2.37	2.47	1.62	2.82	2.81	1.17	1.79	1.47	2.05	3.52	2.22	1.96		2.07	0.67
S5M-l	2.28	3.85	2.57	2.24	1.90	1.48	1.46	1.75	3.29	2.19	2.24	2.76	2.86	1.97	3.22	3.21	1.44	2.16	1.80	2.43	3.91	2.61	2.33		2.43	0.71
S5H-l	2.55	4.10	2.83	2.51	2.16	1.72	1.71	2.01	3.55	2.45	2.51	3.03	3.12	2.24	3.48	3.46	1.68	2.42	2.06	2.70	4.16	2.87	2.60		2.69	0.70
C1L-m	2.63	4.92	3.06	2.57	2.02	1.28	1.26	1.77	4.13	2.48	2.56	3.35	3.50	2.14	4.02	4.00	1.20	2.43	1.86	2.85	5.01	3.12	2.70		2.82	1.08
C1M-m	2.90	5.10	3.33	2.84	2.29	1.52	1.49	2.04	4.35	2.75	2.84	3.61	3.75	2.42	4.25	4.23	1.43	2.70	2.13	3.13	5.19	3.38	2.98		3.07	1.06
C1H-m	2.71	4.50	3.04	2.66	2.23	1.64	1.62	2.03	3.88	2.59	2.66	3.27	3.39	2.32	3.79	3.78	1.58	2.55	2.10	2.88	4.57	3.09	2.77		2.86	0.85
C2L-m	3.01	5.59	3.50	2.94	2.30	1.42	1.39	2.01	4.71	2.84	2.94	3.84	4.00	2.45	4.58	4.56	1.32	2.78	2.12	3.27	5.69	3.57	3.10		3.22	1.24
C2M-m	3.35	5.86	3.84	3.28	2.63	1.70	1.66	2.33	5.01	3.18	3.27	4.16	4.32	2.78	4.89	4.87	1.58	3.12	2.44	3.61	5.96	3.90	3.44		3.53	1.24
C2H-m	3.51	5.80	3.96	3.45	2.86	1.99	1.96	2.58	5.03	3.36	3.45	4.26	4.40	2.99	4.92	4.90	1.88	3.30	2.68	3.75	5.88	4.02	3.59		3.67	1.13
C3L-l	1.53	3.04	1.79	1.50	1.20	0.90	0.89	1.08	2.48	1.45	1.49	1.97	2.06	1.26	2.41	2.40	0.88	1.42	1.13	1.66	3.10	1.82	1.58		1.70	0.64
C3M-l	1.72	3.15	1.97	1.68	1.38	1.02	1.01	1.25	2.64	1.63	1.68	2.15	2.24	1.44	2.57	2.56	0.99	1.60	1.29	1.85	3.21	2.01	1.76		1.86	0.63
C3H-l	2.15	3.50	2.40	2.12	1.82	1.46	1.45	1.69	3.02	2.07	2.12	2.56	2.65	1.89	2.96	2.95	1.42	2.04	1.74	2.28	3.56	2.43	2.19		2.28	0.61
PC1-m	2.34	4.19	2.69	2.29	1.84	1.22	1.20	1.63	3.56	2.22	2.29	2.93	3.05	1.94	3.47	3.45	1.14	2.18	1.71	2.53	4.26	2.74	2.41		2.49	0.88
PC2L-m	2.54	4.89	2.98	2.48	1.93	1.19	1.17	1.68	4.08	2.39	2.48	3.28	3.43	2.05	3.96	3.95	1.12	2.34	1.77	2.77	4.98	3.04	2.62		2.75	1.10
PC2M-m	2.78	5.03	3.21	2.71	2.16	1.38	1.35	1.90	4.26	2.63	2.71	3.50	3.64	2.28	4.15	4.13	1.29	2.58	2.00	3.00	5.12	3.27	2.85		2.95	1.08
PC2H-m	2.85	4.95	3.25	2.79	2.26	1.52	1.49	2.02	4.23	2.71	2.79	3.52	3.66	2.38	4.13	4.12	1.43	2.66	2.11	3.06	5.03	3.31	2.92		3.01	1.02
RM1L-m	2.66	4.71	3.06	2.61	2.10	1.38	1.35	1.86	4.01	2.53	2.60	3.32	3.45	2.21	3.91	3.90	1.29	2.48	1.95	2.87	4.79	3.11	2.73		2.82	0.99
RM1M-m	3.28	5.77	3.77	3.22	2.58	1.67	1.63	2.28	4.93	3.12	3.21	4.09	4.24	2.73	4.81	4.79	1.56	3.06	2.40	3.54	5.86	3.83	3.37		3.47	1.22
RM2L-m	2.69	4.79	3.10	2.64	2.11	1.38	1.35	1.87	4.07	2.55	2.63	3.37	3.50	2.23	3.97	3.96	1.29	2.51	1.96	2.91	4.87	3.15	2.77		2.86	1.01
RM2M-m	3.31	5.84	3.80	3.24	2.60	1.67	1.64	2.30	4.98	3.14	3.24	4.13	4.29	2.75	4.86	4.84	1.56	3.08	2.41	3.57	5.93	3.87	3.40		3.50	1.23
RM2H-m	3.37	5.52	3.79	3.31	2.76	1.95	1.92	2.50	4.80	3.23	3.31	4.07	4.21	2.89	4.69	4.68	1.85	3.18	2.60	3.60	5.60	3.85	3.45		3.53	1.06
URML-l	1.60	2.87	1.83	1.57	1.29	0.96	0.95	1.18	2.42	1.52	1.57	1.99	2.06	1.35	2.35	2.34	0.93	1.50	1.22	1.72	2.92	1.86	1.64		1.72	0.57
URMM-l	1.61	3.17	1.89	1.58	1.26	0.92	0.91	1.13	2.61	1.52	1.58	2.08	2.17	1.33	2.53	2.52	0.89	1.49	1.18	1.76	3.24	1.92	1.66		1.78	0.67
Mean	2.84	4.89	3.23	2.78	2.28	1.59	1.57	2.05	4.19	2.70	2.78	3.49	3.62	2.39	4.09	4.07	1.51	2.66	2.14	3.04	4.97	3.28	2.91		3.00	
Std. Dev.	0.73	1.12	0.81	0.71	0.60	0.41	0.40	0.54	1.00	0.70	0.71	0.86	0.89	0.62	0.98	0.97	0.38	0.68	0.56	0.77	1.14	0.82	0.74			1.22

Table 14. Score given S_{D1}-level shaking in MCE_R high-seismicity locations

	Score Based on S_{D1}-Level Shaking in MCE_R Locations (S')																								
Building Type	**PNW1**	**PNW2**	**PNW3**	**NorCal 1**	**NorCal2**	**NorCal3**	**SoCal1**	**SoCal2**	**SoCal3**	**SoCal4**	**SoCal5**	**SoCal6**	**SoCal7**	**Utah1**	**Utah2**	**NMad1**	**NMad2**	**NMad3**	**SC1**	**SC2**	**NY1**	**PR1**	**AK1**		**Mean Value**	**Standard Deviation**
W1-m	4.52	7.41	5.38	4.47	4.44	2.71	2.84	3.53	6.12	3.93	4.21	5.22	5.44	4.18	6.57	6.76	2.66	4.66	3.76	5.28	7.93	5.18	4.81		4.87	1.41
W2-m	4.00	6.56	4.75	3.95	3.93	2.45	2.55	3.13	5.40	3.49	3.73	4.61	4.80	3.70	5.81	5.97	2.41	4.12	3.34	4.66	7.03	4.58	4.25		4.31	1.24
S1L-m	2.57	4.52	3.12	2.53	2.52	1.52	1.59	1.96	3.62	2.20	2.37	3.02	3.16	2.35	3.94	4.06	1.50	2.66	2.10	3.06	4.90	2.99	2.75		2.83	0.91
S1M-m	2.64	4.33	3.12	2.61	2.59	1.72	1.78	2.11	3.55	2.32	2.47	3.03	3.16	2.45	3.83	3.94	1.69	2.72	2.23	3.07	4.65	3.01	2.80		2.86	0.79
S1H-m	2.70	4.15	3.11	2.67	2.66	1.90	1.95	2.24	3.48	2.42	2.55	3.03	3.14	2.54	3.71	3.81	1.88	2.76	2.34	3.06	4.42	3.01	2.83		2.89	0.68
S2L-m	2.61	4.56	3.17	2.57	2.56	1.55	1.62	2.00	3.66	2.24	2.41	3.06	3.20	2.39	3.98	4.10	1.52	2.70	2.14	3.10	4.93	3.04	2.79		2.87	0.91
S2M-m	2.99	4.92	3.55	2.95	2.93	1.88	1.95	2.36	4.04	2.61	2.79	3.44	3.59	2.77	4.35	4.47	1.85	3.08	2.50	3.48	5.28	3.42	3.18		3.23	0.92
S2H-m	3.11	4.81	3.61	3.08	3.07	2.11	2.18	2.55	4.04	2.78	2.94	3.51	3.64	2.92	4.31	4.42	2.09	3.19	2.68	3.55	5.12	3.49	3.28		3.33	0.81
S3-m	2.61	4.23	3.06	2.58	2.57	1.80	1.85	2.13	3.47	2.32	2.46	2.98	3.09	2.44	3.73	3.84	1.79	2.68	2.24	3.01	4.54	2.96	2.76		2.83	0.74
S4L-m	2.47	4.41	3.01	2.43	2.41	1.46	1.52	1.88	3.51	2.11	2.27	2.91	3.05	2.26	3.82	3.95	1.44	2.55	2.01	2.95	4.78	2.88	2.65		2.73	0.90
S4M-m	2.83	4.70	3.36	2.79	2.78	1.79	1.85	2.23	3.84	2.47	2.64	3.26	3.40	2.62	4.14	4.26	1.76	2.91	2.37	3.30	5.05	3.24	3.01		3.07	0.88
S4H-m	3.07	4.85	3.58	3.03	3.02	2.05	2.12	2.49	4.03	2.72	2.88	3.48	3.62	2.87	4.32	4.43	2.03	3.15	2.62	3.52	5.18	3.46	3.24		3.29	0.84
S5L-l	1.71	3.01	2.06	1.69	1.68	1.20	1.22	1.39	2.38	1.51	1.60	1.99	2.08	1.59	2.60	2.69	1.19	1.77	1.46	2.01	3.28	1.97	1.82		1.91	0.56
S5M-l	2.08	3.41	2.44	2.05	2.04	1.47	1.50	1.71	2.78	1.85	1.95	2.37	2.46	1.94	2.99	3.08	1.46	2.13	1.79	2.39	3.68	2.35	2.20		2.27	0.59
S5H-l	2.34	3.66	2.70	2.32	2.31	1.72	1.75	1.97	3.04	2.11	2.22	2.63	2.73	2.21	3.25	3.34	1.70	2.40	2.05	2.66	3.92	2.62	2.46		2.53	0.60
C1L-m	2.30	4.29	2.86	2.27	2.25	1.27	1.33	1.70	3.37	1.94	2.11	2.76	2.90	2.09	3.69	3.82	1.25	2.39	1.83	2.80	4.67	2.73	2.49		2.57	0.92
C1M-m	2.58	4.51	3.14	2.55	2.53	1.51	1.58	1.97	3.63	2.21	2.39	3.03	3.17	2.37	3.93	4.06	1.48	2.67	2.11	3.07	4.87	3.01	2.77		2.83	0.91
C1H-m	2.45	4.01	2.89	2.42	2.41	1.64	1.69	1.98	3.29	2.17	2.30	2.81	2.92	2.29	3.54	3.64	1.62	2.52	2.08	2.84	4.31	2.79	2.60		2.66	0.72
C2L-m	2.64	4.89	3.28	2.60	2.58	1.41	1.49	1.93	3.86	2.21	2.41	3.16	3.33	2.39	4.22	4.36	1.38	2.74	2.09	3.21	5.32	3.13	2.86		2.93	1.05
C2M-m	2.97	5.19	3.62	2.93	2.91	1.68	1.77	2.24	4.18	2.54	2.74	3.50	3.66	2.72	4.54	4.68	1.65	3.08	2.41	3.54	5.60	3.47	3.19		3.25	1.06
C2H-m	3.17	5.19	3.76	3.13	3.11	1.98	2.06	2.50	4.27	2.77	2.96	3.65	3.80	2.94	4.59	4.72	1.95	3.26	2.66	3.69	5.56	3.62	3.37		3.42	0.97
C3L-l	1.35	2.60	1.67	1.33	1.32	0.90	0.92	1.05	1.98	1.16	1.25	1.61	1.69	1.24	2.19	2.28	0.89	1.40	1.12	1.63	2.86	1.59	1.45		1.54	0.53
C3M-l	1.53	2.74	1.86	1.51	1.50	1.01	1.04	1.21	2.16	1.34	1.43	1.79	1.88	1.42	2.36	2.44	1.00	1.58	1.28	1.82	2.99	1.78	1.64		1.71	0.53
C3H-l	1.97	3.12	2.28	1.95	1.95	1.45	1.48	1.66	2.57	1.78	1.87	2.22	2.31	1.86	2.76	2.84	1.44	2.02	1.73	2.25	3.35	2.21	2.08		2.14	0.51
PC1-m	2.08	3.69	2.54	2.05	2.03	1.21	1.26	1.58	2.94	1.78	1.92	2.45	2.57	1.90	3.20	3.31	1.19	2.15	1.69	2.48	3.99	2.43	2.23		2.29	0.75
PC2L-m	2.22	4.25	2.79	2.18	2.16	1.18	1.25	1.61	3.30	1.85	2.02	2.68	2.82	2.00	3.63	3.76	1.16	2.31	1.74	2.72	4.64	2.65	2.41		2.49	0.93
PC2M-m	2.45	4.42	3.01	2.41	2.40	1.37	1.44	1.83	3.51	2.08	2.25	2.91	3.05	2.23	3.83	3.96	1.34	2.54	1.97	2.95	4.79	2.88	2.64		2.71	0.92
PC2H-m	2.54	4.38	3.07	2.50	2.49	1.50	1.57	1.95	3.54	2.19	2.35	2.97	3.11	2.33	3.84	3.95	1.48	2.62	2.08	3.01	4.73	2.95	2.72		2.78	0.87
RM1L-m	2.37	4.16	2.88	2.33	2.32	1.37	1.43	1.79	3.34	2.02	2.18	2.78	2.92	2.17	3.62	3.74	1.34	2.45	1.92	2.82	4.49	2.76	2.54		2.60	0.84
RM1M-m	2.92	5.10	3.55	2.88	2.86	1.65	1.74	2.20	4.11	2.49	2.69	3.43	3.59	2.67	4.46	4.60	1.62	3.02	2.37	3.47	5.51	3.40	3.13		3.19	1.04
RM2L-m	2.39	4.22	2.92	2.36	2.34	1.37	1.44	1.81	3.38	2.04	2.20	2.81	2.95	2.19	3.68	3.79	1.34	2.47	1.94	2.85	4.56	2.79	2.57		2.63	0.86
RM2M-m	2.94	5.16	3.58	2.90	2.88	1.66	1.74	2.21	4.15	2.51	2.71	3.46	3.63	2.69	4.50	4.65	1.63	3.04	2.38	3.51	5.57	3.43	3.16		3.22	1.06
RM2H-m	3.05	4.95	3.61	3.02	3.00	1.94	2.01	2.43	4.09	2.68	2.85	3.50	3.64	2.84	4.39	4.51	1.91	3.14	2.57	3.54	5.30	3.48	3.24		3.29	0.91
URML-l	1.44	2.51	1.73	1.42	1.41	0.96	0.98	1.14	2.00	1.26	1.34	1.67	1.75	1.33	2.17	2.24	0.95	1.48	1.21	1.69	2.72	1.66	1.53		1.59	0.48
URMM-l	1.42	2.72	1.76	1.40	1.39	0.92	0.94	1.10	2.09	1.22	1.31	1.69	1.79	1.30	2.30	2.39	0.91	1.47	1.17	1.72	2.99	1.68	1.53		1.62	0.56
Mean	2.54	4.33	3.05	2.51	2.50	1.58	1.64	1.99	3.51	2.21	2.36	2.95	3.09	2.35	3.79	3.91	1.56	2.62	2.11	2.99	4.67	2.93	2.71		2.78	
Std. Dev.	0.66	1.02	0.77	0.65	0.65	0.40	0.42	0.52	0.87	0.58	0.62	0.75	0.78	0.61	0.92	0.94	0.40	0.68	0.55	0.76	1.08	0.75	0.70			1.08

Table 15. Score based on risk integral in high-seismicity locations

	Score Based on Risk Integral (S_R)																									
Building Type	PNW1	PNW2	PNW3	NorCal 1	NorCal2	NorCal3	SoCal1	SoCal2	SoCal3	SoCal4	SoCal5	SoCal6	SoCal7	Utah1	Utah2	NMad1	NMad2	NMad3	SC1	SC2	NY1	PR1	AK1		Mean Value	Standard Deviation
W1-m	3.78	5.10	4.13	4.04	3.42	2.83	2.78	3.31	5.27	3.81	3.87	4.74	4.86	3.43	5.20	4.67	2.85	3.61	3.22	3.74	4.64	4.61	5.40		4.06	0.82
W2-m	3.58	4.83	3.91	3.71	3.18	2.68	2.62	3.11	4.93	3.56	3.61	4.40	4.51	3.28	4.92	4.45	2.74	3.44	3.10	3.59	4.47	4.26	5.03		3.82	0.76
S1L-m	2.67	3.75	2.95	2.54	2.18	1.89	1.81	2.24	3.64	2.52	2.55	3.17	3.24	2.50	3.84	3.43	2.05	2.61	2.39	2.78	3.58	3.03	3.79		2.83	0.63
S1M-m	2.82	3.86	3.10	2.64	2.32	2.07	1.99	2.40	3.67	2.64	2.65	3.24	3.30	2.68	3.96	3.55	2.25	2.78	2.58	2.96	3.73	3.11	3.87		2.96	0.60
S1H-m	2.94	3.94	3.21	2.71	2.43	2.23	2.16	2.55	3.67	2.73	2.72	3.27	3.31	2.85	4.05	3.64	2.45	2.93	2.76	3.12	3.85	3.15	3.92		3.07	0.56
S2L-m	2.70	3.78	2.98	2.57	2.21	1.91	1.83	2.26	3.67	2.55	2.58	3.20	3.28	2.52	3.87	3.46	2.07	2.63	2.41	2.81	3.61	3.07	3.83		2.86	0.63
S2M-m	3.02	4.13	3.31	2.93	2.55	2.21	2.14	2.58	4.04	2.90	2.92	3.56	3.64	2.82	4.22	3.80	2.35	2.94	2.69	3.11	3.93	3.43	4.19		3.19	0.65
S2H-m	3.22	4.30	3.51	3.09	2.74	2.44	2.36	2.80	4.14	3.07	3.09	3.69	3.76	3.05	4.40	3.98	2.58	3.16	2.92	3.33	4.13	3.57	4.33		3.38	0.62
S3-m	2.87	3.87	3.14	2.64	2.36	2.16	2.08	2.47	3.64	2.66	2.66	3.22	3.27	2.77	3.98	3.57	2.38	2.85	2.70	3.04	3.78	3.09	3.86		3.00	0.57
S4L-m	2.61	3.67	2.88	2.45	2.11	1.84	1.76	2.17	3.54	2.45	2.47	3.07	3.15	2.45	3.76	3.35	2.02	2.55	2.35	2.73	3.51	2.94	3.70		2.76	0.62
S4M-m	2.93	4.00	3.21	2.80	2.44	2.14	2.06	2.49	3.88	2.78	2.80	3.42	3.49	2.75	4.10	3.69	2.29	2.86	2.63	3.03	3.83	3.29	4.05		3.08	0.63
S4H-m	3.18	4.25	3.46	3.04	2.69	2.39	2.32	2.74	4.11	3.03	3.04	3.66	3.72	3.00	4.35	3.93	2.54	3.11	2.88	3.28	4.08	3.53	4.29		3.33	0.62
S5L-l	2.08	3.01	2.34	1.75	1.55	1.49	1.40	1.75	2.64	1.81	1.78	2.28	2.30	2.11	3.14	2.72	1.81	2.15	2.08	2.34	2.99	2.17	2.93		2.20	0.51
S5M-l	2.41	3.36	2.68	2.10	1.89	1.78	1.70	2.06	3.01	2.16	2.13	2.64	2.67	2.40	3.48	3.07	2.07	2.46	2.36	2.65	3.32	2.53	3.29		2.53	0.52
S5H-l	2.67	3.62	2.93	2.37	2.14	2.03	1.95	2.31	3.27	2.41	2.39	2.90	2.93	2.65	3.74	3.33	2.31	2.71	2.61	2.90	3.58	2.79	3.55		2.79	0.53
C1L-m	2.42	3.49	2.70	2.28	1.93	1.64	1.57	1.99	3.38	2.27	2.29	2.91	2.98	2.25	3.58	3.18	1.82	2.36	2.15	2.54	3.33	2.77	3.54		2.58	0.62
C1M-m	2.65	3.74	2.94	2.54	2.17	1.86	1.78	2.21	3.64	2.52	2.54	3.17	3.24	2.46	3.84	3.42	2.01	2.58	2.35	2.75	3.56	3.04	3.80		2.82	0.64
C1H-m	2.70	3.71	2.97	2.47	2.19	1.98	1.91	2.30	3.46	2.49	2.49	3.05	3.10	2.60	3.81	3.40	2.20	2.68	2.52	2.87	3.61	2.92	3.69		2.83	0.57
C2L-m	2.59	3.72	2.88	2.54	2.13	1.76	1.69	2.14	3.70	2.49	2.52	3.19	3.29	2.37	3.80	3.39	1.90	2.50	2.24	2.67	3.50	3.06	3.82		2.78	0.67
C2M-m	2.85	4.00	3.15	2.84	2.40	1.99	1.93	2.39	4.01	2.76	2.81	3.50	3.59	2.60	4.09	3.66	2.10	2.74	2.45	2.90	3.74	3.36	4.12		3.04	0.69
C2H-m	3.13	4.26	3.43	3.08	2.67	2.29	2.22	2.68	4.21	3.02	3.06	3.72	3.81	2.90	4.35	3.93	2.41	3.03	2.75	3.19	4.02	3.59	4.35		3.31	0.67
C3L-l	1.73	2.65	1.99	1.38	1.20	1.16	1.08	1.41	2.25	1.44	1.41	1.90	1.92	1.78	2.78	2.36	1.50	1.82	1.77	2.01	2.64	1.79	2.56		1.85	0.50
C3M-l	1.89	2.81	2.15	1.55	1.36	1.30	1.21	1.56	2.42	1.61	1.57	2.07	2.09	1.92	2.94	2.53	1.61	1.96	1.89	2.16	2.79	1.96	2.72		2.00	0.51
C3H-l	2.31	3.23	2.58	1.98	1.79	1.73	1.65	1.99	2.82	2.03	2.00	2.48	2.50	2.35	3.36	2.95	2.04	2.40	2.32	2.59	3.22	2.38	3.14		2.43	0.50
PC1-m	2.29	3.31	2.56	2.08	1.79	1.56	1.48	1.88	3.10	2.10	2.10	2.67	2.73	2.17	3.42	3.01	1.75	2.26	2.08	2.44	3.20	2.55	3.31		2.43	0.58
PC2L-m	2.34	3.40	2.62	2.20	1.85	1.56	1.49	1.90	3.30	2.18	2.21	2.82	2.90	2.17	3.50	3.09	1.74	2.28	2.07	2.46	3.25	2.69	3.45		2.50	0.62
PC2M-m	2.52	3.61	2.81	2.41	2.04	1.72	1.65	2.08	3.51	2.38	2.41	3.04	3.12	2.33	3.70	3.29	1.88	2.45	2.22	2.62	3.43	2.90	3.67		2.69	0.64
PC2H-m	2.64	3.72	2.92	2.51	2.15	1.85	1.78	2.20	3.59	2.49	2.51	3.13	3.20	2.46	3.81	3.40	2.00	2.57	2.34	2.74	3.54	3.00	3.76		2.80	0.63
RM1L-m	2.49	3.56	2.77	2.35	2.00	1.71	1.64	2.06	3.41	2.34	2.35	2.96	3.03	2.32	3.65	3.24	1.88	2.43	2.21	2.61	3.40	2.83	3.59		2.64	0.62
RM1M-m	2.82	3.97	3.12	2.80	2.37	1.97	1.90	2.36	3.96	2.73	2.77	3.45	3.55	2.58	4.06	3.63	2.08	2.72	2.44	2.88	3.72	3.32	4.08		3.01	0.69
RM2L-m	2.50	3.57	2.78	2.36	2.02	1.72	1.64	2.07	3.44	2.35	2.37	2.98	3.05	2.33	3.67	3.26	1.88	2.44	2.22	2.61	3.41	2.85	3.61		2.66	0.62
RM2M-m	2.83	3.98	3.13	2.81	2.37	1.98	1.91	2.37	3.98	2.74	2.78	3.47	3.56	2.58	4.07	3.64	2.09	2.72	2.44	2.88	3.72	3.33	4.09		3.02	0.69
RM2H-m	3.08	4.19	3.37	2.99	2.61	2.26	2.19	2.63	4.10	2.95	2.98	3.62	3.70	2.86	4.28	3.86	2.38	2.99	2.73	3.16	3.97	3.49	4.25		3.25	0.65
URML-l	1.78	2.68	2.05	1.43	1.25	1.21	1.13	1.47	2.24	1.49	1.44	1.92	1.93	1.83	2.82	2.41	1.55	1.88	1.82	2.07	2.68	1.82	2.57		1.89	0.49
URMM-l	1.79	2.72	2.06	1.46	1.26	1.20	1.12	1.46	2.35	1.52	1.49	1.99	2.01	1.82	2.85	2.43	1.53	1.87	1.80	2.06	2.70	1.88	2.64		1.91	0.51
Mean	2.65	3.71	2.94	2.50	2.16	1.90	1.83	2.24	3.54	2.49	2.50	3.10	3.16	2.51	3.81	3.39	2.09	2.61	2.41	2.79	3.56	2.97	3.74		2.81	
Std. Dev.	0.47	0.55	0.48	0.58	0.50	0.39	0.40	0.43	0.67	0.53	0.55	0.63	0.65	0.39	0.54	0.52	0.34	0.41	0.35	0.40	0.46	0.62	0.62			0.77

Table 16. Performance modification factor given S_{D1}-level shaking in MCE high-seismicity locations

	Performance Modification Factor Based on S_{D1}-Level Shaking in MCE Locations (PMF)																									
Building Type	PNW1	PNW2	PNW3	NorCal 1	NorCal2	NorCal3	SoCal1	SoCal2	SoCal3	SoCal4	SoCal5	SoCal6	SoCal7	Utah1	Utah2	NMad1	NMad2	NMad3	SC1	SC2	NY1	PR1	AK1		Mean Value	Standard Deviation
W1-m	-1.24	-3.16	-1.54	-0.89	-0.65	0.10	0.09	-0.33	-1.91	-0.99	-1.06	-1.36	-1.44	-0.83	-1.83	-2.34	0.29	-1.10	-0.59	-1.63	-3.74	-1.14	0.26		-1.18	1.01
W2-m	-0.85	-2.50	-1.09	-0.65	-0.42	0.21	0.19	-0.12	-1.43	-0.68	-0.74	-0.99	-1.06	-0.49	-1.30	-1.75	0.42	-0.73	-0.27	-1.15	-2.97	-0.82	0.49		-0.81	0.84
S1L-m	-0.22	-1.39	-0.36	-0.29	-0.10	0.35	0.30	0.21	-0.73	-0.22	-0.28	-0.44	-0.50	0.09	-0.42	-0.81	0.60	-0.08	0.27	-0.33	-1.65	-0.34	0.83		-0.24	0.57
S1M-m	-0.10	-1.00	-0.19	-0.23	-0.07	0.34	0.29	0.23	-0.52	-0.15	-0.21	-0.30	-0.36	0.18	-0.14	-0.54	0.60	0.03	0.33	-0.16	-1.21	-0.23	0.89		-0.11	0.47
S1H-m	0.01	-0.66	-0.04	-0.19	-0.05	0.33	0.27	0.26	-0.36	-0.09	-0.16	-0.20	-0.26	0.27	0.10	-0.30	0.61	0.15	0.40	0.01	-0.82	-0.14	0.92		0.00	0.38
S2L-m	-0.23	-1.39	-0.38	-0.30	-0.11	0.35	0.30	0.19	-0.73	-0.23	-0.29	-0.44	-0.51	0.07	-0.42	-0.82	0.60	-0.10	0.25	-0.35	-1.65	-0.35	0.82		-0.25	0.57
S2M-m	-0.29	-1.38	-0.42	-0.32	-0.14	0.32	0.28	0.15	-0.73	-0.27	-0.32	-0.46	-0.52	0.00	-0.44	-0.84	0.56	-0.17	0.16	-0.43	-1.67	-0.36	0.80		-0.28	0.56
S2H-m	-0.18	-1.02	-0.27	-0.26	-0.11	0.31	0.27	0.18	-0.54	-0.20	-0.26	-0.33	-0.39	0.08	-0.18	-0.59	0.55	-0.06	0.22	-0.27	-1.27	-0.26	0.86		-0.16	0.46
S3-m	0.00	-0.87	-0.08	-0.19	-0.03	0.35	0.29	0.28	-0.46	-0.09	-0.16	-0.24	-0.31	0.29	-0.02	-0.42	0.63	0.14	0.44	-0.01	-1.04	-0.17	0.93		-0.03	0.44
S4L-m	-0.17	-1.36	-0.32	-0.27	-0.07	0.36	0.31	0.23	-0.71	-0.19	-0.25	-0.42	-0.48	0.14	-0.38	-0.77	0.62	-0.04	0.32	-0.27	-1.60	-0.32	0.85		-0.21	0.57
S4M-m	-0.21	-1.28	-0.34	-0.28	-0.11	0.34	0.29	0.19	-0.67	-0.22	-0.28	-0.41	-0.47	0.08	-0.35	-0.74	0.58	-0.09	0.24	-0.32	-1.53	-0.32	0.84		-0.22	0.54
S4H-m	-0.19	-1.14	-0.30	-0.27	-0.11	0.33	0.28	0.19	-0.60	-0.20	-0.26	-0.37	-0.42	0.08	-0.26	-0.66	0.57	-0.07	0.23	-0.29	-1.39	-0.28	0.85		-0.19	0.50
S5L-l	0.17	-0.45	0.16	-0.12	0.00	0.28	0.21	0.33	-0.26	-0.01	-0.09	-0.09	-0.16	0.49	0.31	-0.09	0.63	0.36	0.61	0.30	-0.53	-0.05	0.97		0.13	0.36
S5M-l	0.13	-0.49	0.11	-0.14	-0.01	0.31	0.24	0.31	-0.28	-0.03	-0.11	-0.12	-0.19	0.43	0.26	-0.14	0.63	0.30	0.56	0.22	-0.59	-0.08	0.96		0.10	0.36
S5H-l	0.12	-0.48	0.10	-0.14	-0.02	0.31	0.24	0.31	-0.28	-0.04	-0.12	-0.12	-0.19	0.41	0.26	-0.14	0.63	0.29	0.54	0.20	-0.58	-0.08	0.95		0.10	0.36
C1L-m	-0.20	-1.43	-0.36	-0.28	-0.09	0.36	0.31	0.22	-0.75	-0.21	-0.27	-0.44	-0.51	0.11	-0.43	-0.82	0.62	-0.07	0.29	-0.32	-1.68	-0.34	0.83		-0.24	0.58
C1M-m	-0.25	-1.36	-0.39	-0.30	-0.12	0.34	0.29	0.18	-0.71	-0.24	-0.30	-0.44	-0.50	0.05	-0.41	-0.81	0.58	-0.12	0.21	-0.37	-1.63	-0.35	0.82		-0.25	0.56
C1H-m	-0.01	-0.79	-0.08	-0.19	-0.04	0.34	0.28	0.27	-0.42	-0.10	-0.17	-0.23	-0.29	0.27	0.02	-0.38	0.62	0.13	0.41	-0.02	-0.96	-0.17	0.92		-0.02	0.42
C2L-m	-0.42	-1.87	-0.62	-0.40	-0.18	0.34	0.30	0.12	-1.01	-0.35	-0.41	-0.64	-0.71	-0.08	-0.78	-1.17	0.58	-0.28	0.12	-0.60	-2.19	-0.51	0.71		-0.44	0.70
C2M-m	-0.50	-1.86	-0.69	-0.44	-0.23	0.30	0.26	0.06	-1.01	-0.41	-0.47	-0.67	-0.73	-0.18	-0.80	-1.21	0.52	-0.38	0.01	-0.71	-2.22	-0.54	0.69		-0.49	0.68
C2H-m	-0.38	-1.54	-0.53	-0.37	-0.19	0.30	0.26	0.10	-0.81	-0.33	-0.39	-0.53	-0.59	-0.10	-0.57	-0.98	0.52	-0.27	0.07	-0.55	-1.86	-0.43	0.76		-0.37	0.59
C3L-l	0.20	-0.39	0.20	-0.11	-0.01	0.26	0.18	0.33	-0.23	0.00	-0.09	-0.07	-0.14	0.52	0.37	-0.04	0.62	0.40	0.64	0.35	-0.46	-0.03	0.98		0.15	0.35
C3M-l	0.17	-0.34	0.18	-0.13	-0.02	0.28	0.21	0.31	-0.22	-0.02	-0.11	-0.08	-0.15	0.47	0.37	-0.03	0.63	0.36	0.60	0.30	-0.42	-0.05	0.96		0.14	0.34
C3H-l	0.16	-0.27	0.19	-0.14	-0.03	0.27	0.20	0.30	-0.20	-0.03	-0.12	-0.08	-0.15	0.46	0.41	0.01	0.62	0.36	0.59	0.31	-0.33	-0.05	0.94		0.15	0.32
PC1-m	-0.05	-0.88	-0.13	-0.21	-0.05	0.34	0.28	0.25	-0.46	-0.12	-0.19	-0.26	-0.32	0.23	-0.05	-0.44	0.61	0.08	0.37	-0.08	-1.07	-0.19	0.91		-0.06	0.44
PC2L-m	-0.21	-1.48	-0.37	-0.29	-0.08	0.37	0.32	0.23	-0.78	-0.21	-0.27	-0.46	-0.53	0.12	-0.47	-0.85	0.62	-0.06	0.31	-0.32	-1.73	-0.35	0.83		-0.25	0.60
PC2M-m	-0.25	-1.42	-0.40	-0.31	-0.12	0.34	0.30	0.18	-0.75	-0.24	-0.30	-0.46	-0.52	0.05	-0.45	-0.85	0.59	-0.13	0.22	-0.38	-1.69	-0.36	0.81		-0.27	0.57
PC2H-m	-0.21	-1.24	-0.33	-0.28	-0.11	0.33	0.29	0.19	-0.64	-0.21	-0.27	-0.40	-0.46	0.08	-0.32	-0.72	0.58	-0.09	0.24	-0.32	-1.49	-0.31	0.84		-0.21	0.52
RM1L-m	-0.17	-1.15	-0.28	-0.26	-0.09	0.34	0.29	0.20	-0.60	-0.19	-0.25	-0.36	-0.42	0.11	-0.26	-0.66	0.59	-0.05	0.26	-0.26	-1.39	-0.28	0.86		-0.18	0.50
RM1M-m	-0.46	-1.80	-0.65	-0.42	-0.22	0.30	0.27	0.08	-0.97	-0.39	-0.44	-0.64	-0.70	-0.15	-0.75	-1.16	0.53	-0.34	0.04	-0.66	-2.14	-0.51	0.71		-0.46	0.67
RM2L-m	-0.19	-1.21	-0.31	-0.27	-0.10	0.34	0.29	0.20	-0.63	-0.20	-0.26	-0.38	-0.44	0.09	-0.30	-0.70	0.58	-0.07	0.25	-0.29	-1.46	-0.30	0.85		-0.20	0.52
RM2M-m	-0.49	-1.86	-0.67	-0.43	-0.23	0.30	0.27	0.07	-1.00	-0.40	-0.46	-0.66	-0.72	-0.16	-0.79	-1.20	0.53	-0.36	0.03	-0.69	-2.21	-0.53	0.69		-0.48	0.68
RM2H-m	-0.30	-1.34	-0.42	-0.32	-0.15	0.31	0.27	0.13	-0.70	-0.27	-0.33	-0.45	-0.51	-0.02	-0.42	-0.82	0.54	-0.19	0.13	-0.44	-1.63	-0.36	0.80		-0.28	0.54
URML-l	0.18	-0.19	0.22	-0.14	-0.04	0.25	0.18	0.29	-0.17	-0.04	-0.13	-0.07	-0.14	0.48	0.46	0.07	0.62	0.38	0.60	0.35	-0.23	-0.04	0.93		0.17	0.31
URMM-l	0.18	-0.45	0.17	-0.12	0.00	0.28	0.21	0.33	-0.26	-0.01	-0.09	-0.09	-0.16	0.49	0.32	-0.08	0.63	0.37	0.62	0.30	-0.53	-0.05	0.98		0.13	0.36
Mean	-0.18	-1.18	-0.29	-0.28	-0.12	0.31	0.26	0.19	-0.64	-0.22	-0.28	-0.39	-0.46	0.12	-0.28	-0.68	0.58	-0.04	0.28	-0.25	-1.42	-0.31	0.83		-0.19	
Std. Dev.	0.30	0.64	0.37	0.15	0.12	0.05	0.05	0.13	0.36	0.20	0.19	0.27	0.27	0.28	0.49	0.51	0.07	0.32	0.26	0.43	0.75	0.23	0.14			0.60

Table 17. Performance modification factor given S_{D1}-level shaking in MCE_R high-seismicity locations

	Performance Modification Factor Based on S_{D1}-Level Shaking in MCE_R Locations (PMF')																									
Building Type	PNW1	PNW2	PNW3	NorCal1	NorCal2	NorCal3	SoCal1	SoCal2	SoCal3	SoCal4	SoCal5	SoCal6	SoCal7	Utah1	Utah2	NMad1	NMad2	NMad3	SC1	SC2	NY1	PR1	AK1		Mean Value	Standard Deviation
W1-m	-0.75	-2.31	-1.25	-0.43	-1.02	0.12	-0.06	-0.22	-0.85	-0.13	-0.34	-0.48	-0.58	-0.75	-1.37	-2.08	0.19	-1.05	-0.54	-1.54	-3.29	-0.57	0.58		-0.81	0.88
W2-m	-0.42	-1.73	-0.84	-0.24	-0.75	0.23	0.06	-0.02	-0.48	0.07	-0.11	-0.21	-0.30	-0.42	-0.90	-1.53	0.33	-0.68	-0.24	-1.07	-2.56	-0.32	0.78		-0.49	0.73
S1L-m	0.10	-0.78	-0.17	0.01	-0.33	0.37	0.22	0.27	0.02	0.32	0.17	0.15	0.08	0.14	-0.10	-0.63	0.55	-0.05	0.29	-0.27	-1.32	0.04	1.04		0.01	0.47
S1M-m	0.18	-0.47	-0.03	0.03	-0.27	0.35	0.22	0.29	0.12	0.32	0.18	0.21	0.14	0.22	0.14	-0.38	0.56	0.06	0.35	-0.11	-0.93	0.10	1.07		0.10	0.38
S1H-m	0.25	-0.21	0.10	0.04	-0.22	0.34	0.21	0.31	0.19	0.31	0.18	0.24	0.18	0.31	0.34	-0.17	0.57	0.17	0.42	0.06	-0.57	0.14	1.08		0.18	0.31
S2L-m	0.09	-0.78	-0.18	0.00	-0.34	0.36	0.22	0.26	0.01	0.31	0.17	0.14	0.07	0.12	-0.10	-0.64	0.54	-0.07	0.27	-0.29	-1.33	0.03	1.04		0.00	0.47
S2M-m	0.04	-0.79	-0.23	-0.02	-0.38	0.34	0.19	0.22	0.00	0.28	0.14	0.12	0.06	0.05	-0.13	-0.67	0.50	-0.13	0.19	-0.37	-1.35	0.01	1.02		-0.04	0.47
S2H-m	0.11	-0.51	-0.10	0.01	-0.32	0.33	0.18	0.24	0.10	0.29	0.15	0.18	0.12	0.12	0.09	-0.44	0.50	-0.03	0.24	-0.22	-0.99	0.07	1.05		0.05	0.39
S3-m	0.26	-0.35	0.07	0.05	-0.21	0.36	0.23	0.34	0.17	0.34	0.20	0.24	0.18	0.33	0.25	-0.27	0.60	0.17	0.46	0.03	-0.76	0.14	1.10		0.17	0.36
S4L-m	0.14	-0.74	-0.13	0.02	-0.30	0.37	0.24	0.30	0.04	0.34	0.19	0.17	0.10	0.19	-0.06	-0.59	0.58	0.00	0.34	-0.22	-1.27	0.06	1.06		0.03	0.46
S4M-m	0.10	-0.70	-0.16	0.00	-0.34	0.35	0.21	0.26	0.04	0.31	0.16	0.16	0.09	0.13	-0.04	-0.58	0.53	-0.05	0.27	-0.27	-1.22	0.05	1.04		0.02	0.45
S4H-m	0.11	-0.60	-0.12	0.01	-0.33	0.34	0.20	0.25	0.07	0.30	0.16	0.17	0.11	0.13	0.03	-0.50	0.52	-0.04	0.26	-0.24	-1.10	0.06	1.05		0.04	0.42
S5L-l	0.37	0.00	0.29	0.06	-0.13	0.29	0.18	0.36	0.26	0.30	0.17	0.29	0.22	0.51	0.54	0.04	0.62	0.39	0.63	0.33	-0.29	0.19	1.11		0.29	0.28
S5M-l	0.34	-0.05	0.24	0.05	-0.16	0.31	0.20	0.35	0.24	0.30	0.18	0.28	0.21	0.46	0.49	-0.01	0.61	0.33	0.57	0.26	-0.35	0.18	1.10		0.27	0.29
S5H-l	0.33	-0.05	0.23	0.05	-0.17	0.32	0.20	0.35	0.23	0.30	0.17	0.27	0.20	0.44	0.49	-0.01	0.61	0.31	0.56	0.24	-0.35	0.17	1.09		0.26	0.29
C1L-m	0.12	-0.80	-0.16	0.01	-0.32	0.37	0.23	0.29	0.01	0.33	0.18	0.15	0.08	0.16	-0.11	-0.64	0.57	-0.03	0.32	-0.26	-1.34	0.04	1.04		0.01	0.48
C1M-m	0.07	-0.77	-0.20	-0.01	-0.36	0.35	0.20	0.25	0.01	0.30	0.16	0.14	0.07	0.10	-0.10	-0.64	0.52	-0.09	0.24	-0.32	-1.31	0.03	1.03		-0.01	0.47
C1H-m	0.24	-0.30	0.08	0.04	-0.22	0.35	0.22	0.32	0.17	0.33	0.19	0.24	0.17	0.31	0.27	-0.24	0.58	0.16	0.43	0.03	-0.70	0.13	1.09		0.17	0.34
C2L-m	-0.05	-1.17	-0.40	-0.06	-0.45	0.35	0.20	0.20	-0.16	0.27	0.11	0.03	-0.04	-0.02	-0.41	-0.97	0.52	-0.24	0.15	-0.54	-1.82	-0.08	0.96		-0.16	0.58
C2M-m	-0.13	-1.19	-0.47	-0.09	-0.51	0.31	0.16	0.14	-0.18	0.22	0.06	0.00	-0.07	-0.12	-0.44	-1.02	0.45	-0.34	0.04	-0.64	-1.86	-0.10	0.93		-0.21	0.58
C2H-m	-0.04	-0.93	-0.33	-0.05	-0.44	0.31	0.16	0.18	-0.06	0.25	0.10	0.08	0.01	-0.04	-0.24	-0.80	0.46	-0.23	0.10	-0.50	-1.53	-0.03	0.98		-0.11	0.51
C3L-l	0.38	0.05	0.32	0.05	-0.13	0.26	0.16	0.36	0.27	0.28	0.16	0.29	0.23	0.54	0.58	0.08	0.61	0.42	0.65	0.38	-0.22	0.20	1.10		0.31	0.28
C3M-l	0.35	0.06	0.29	0.04	-0.15	0.28	0.17	0.35	0.25	0.27	0.15	0.27	0.21	0.50	0.58	0.08	0.61	0.38	0.61	0.34	-0.20	0.18	1.08		0.29	0.27
C3H-l	0.34	0.11	0.30	0.02	-0.16	0.27	0.17	0.34	0.25	0.26	0.13	0.26	0.19	0.49	0.60	0.12	0.60	0.38	0.60	0.34	-0.13	0.17	1.06		0.29	0.26
PC1-m	0.21	-0.37	0.03	0.04	-0.25	0.35	0.22	0.31	0.15	0.32	0.19	0.23	0.16	0.27	0.22	-0.30	0.57	0.11	0.39	-0.04	-0.80	0.12	1.08		0.14	0.36
PC2L-m	0.12	-0.84	-0.17	0.02	-0.32	0.38	0.24	0.29	0.00	0.34	0.19	0.15	0.08	0.17	-0.13	-0.67	0.58	-0.03	0.33	-0.26	-1.39	0.04	1.04		0.01	0.49
PC2M-m	0.07	-0.81	-0.21	-0.01	-0.36	0.36	0.21	0.25	0.00	0.31	0.16	0.13	0.06	0.10	-0.13	-0.67	0.53	-0.09	0.25	-0.32	-1.37	0.02	1.03		-0.02	0.48
PC2H-m	0.10	-0.67	-0.15	0.00	-0.33	0.35	0.20	0.26	0.05	0.31	0.16	0.16	0.09	0.12	-0.02	-0.56	0.53	-0.05	0.26	-0.26	-1.19	0.05	1.04		0.02	0.44
RM1L-m	0.13	-0.60	-0.11	0.01	-0.31	0.35	0.21	0.27	0.08	0.31	0.17	0.18	0.11	0.16	0.03	-0.50	0.54	-0.02	0.29	-0.21	-1.10	0.07	1.05		0.05	0.42
RM1M-m	-0.10	-1.13	-0.43	-0.08	-0.49	0.32	0.17	0.16	-0.15	0.24	0.08	0.02	-0.05	-0.09	-0.40	-0.97	0.46	-0.30	0.07	-0.60	-1.79	-0.09	0.95		-0.18	0.57
RM2L-m	0.11	-0.65	-0.13	0.01	-0.32	0.35	0.21	0.26	0.06	0.31	0.17	0.17	0.10	0.14	-0.01	-0.54	0.53	-0.03	0.28	-0.24	-1.16	0.06	1.05		0.03	0.43
RM2M-m	-0.11	-1.18	-0.46	-0.09	-0.50	0.32	0.16	0.15	-0.17	0.23	0.07	0.01	-0.06	-0.11	-0.44	-1.01	0.46	-0.32	0.06	-0.62	-1.85	-0.10	0.94		-0.20	0.58
RM2H-m	0.02	-0.76	-0.24	-0.02	-0.39	0.32	0.17	0.21	0.01	0.27	0.13	0.12	0.06	0.03	-0.11	-0.66	0.48	-0.15	0.16	-0.38	-1.32	0.01	1.01		-0.05	0.46
URML-l	0.34	0.17	0.32	0.01	-0.16	0.25	0.15	0.32	0.25	0.23	0.10	0.25	0.18	0.50	0.65	0.17	0.60	0.40	0.61	0.38	-0.04	0.17	1.04		0.30	0.26
URMM-l	0.37	0.00	0.29	0.06	-0.13	0.28	0.18	0.36	0.26	0.30	0.17	0.29	0.22	0.52	0.54	0.04	0.62	0.39	0.63	0.34	-0.29	0.20	1.11		0.29	0.29
Mean	0.11	-0.62	-0.12	-0.01	-0.33	0.32	0.19	0.25	0.04	0.28	0.13	0.15	0.08	0.16	0.02	-0.52	0.53	-0.01	0.30	-0.20	-1.12	0.04	1.02		0.03	
Std. Dev.	0.23	0.53	0.33	0.09	0.18	0.05	0.05	0.11	0.22	0.09	0.10	0.15	0.16	0.27	0.43	0.47	0.09	0.31	0.25	0.42	0.70	0.15	0.10			0.50

Table 18. Discrepancy factor given S_{M1}-level shaking for MCE high-seismicity locations

Discrepancy Factor Based on S_{M1}-Level Shaking in MCE Locations (D)																									
Building Type	PNW1	PNW2	PNW3	NorCal 1	NorCal2	NorCal3	SoCal1	SoCal2	SoCal3	SoCal4	SoCal5	SoCal6	SoCal7	Utah1	Utah2	NMad1	NMad2	NMad3	SC1	SC2	NY1	PR1	AK1		Mean Value	Standard Deviation
W1-m	0.54	0.24	0.45	0.56	0.74	1.32	1.36	0.87	0.31	0.58	0.56	0.40	0.38	0.69	0.32	0.32	1.46	0.59	0.82	0.49	0.24	0.44	0.52		0.62	0.35
W2-m	0.64	0.29	0.53	0.65	0.87	1.56	1.60	1.02	0.36	0.68	0.66	0.47	0.45	0.81	0.38	0.38	1.72	0.70	0.96	0.58	0.28	0.52	0.61		0.73	0.41
S1L-m	0.98	0.44	0.81	1.01	1.34	2.39	2.46	1.57	0.56	1.05	1.01	0.73	0.69	1.25	0.58	0.58	2.65	1.07	1.47	0.89	0.43	0.79	0.94		1.12	0.63
S1M-m	1.03	0.46	0.86	1.06	1.41	2.52	2.60	1.65	0.59	1.11	1.06	0.77	0.73	1.31	0.61	0.61	2.79	1.13	1.56	0.93	0.45	0.84	1.00		1.18	0.66
S1H-m	1.13	0.51	0.94	1.16	1.55	2.77	2.85	1.82	0.65	1.21	1.17	0.84	0.80	1.44	0.67	0.67	3.07	1.24	1.71	1.03	0.50	0.92	1.09		1.29	0.73
S2L-m	0.95	0.43	0.79	0.98	1.31	2.34	2.40	1.53	0.54	1.02	0.98	0.71	0.67	1.22	0.56	0.57	2.59	1.05	1.44	0.86	0.42	0.78	0.92		1.09	0.61
S2M-m	0.86	0.39	0.71	0.88	1.17	2.10	2.16	1.37	0.49	0.92	0.88	0.64	0.60	1.09	0.51	0.51	2.32	0.94	1.29	0.78	0.38	0.70	0.83		0.98	0.55
S2H-m	0.87	0.39	0.73	0.90	1.19	2.13	2.20	1.40	0.50	0.93	0.90	0.65	0.62	1.11	0.51	0.52	2.36	0.96	1.32	0.79	0.38	0.71	0.84		1.00	0.56
S3-m	1.21	0.54	1.01	1.24	1.66	2.96	3.05	1.94	0.69	1.30	1.25	0.90	0.85	1.54	0.71	0.72	3.28	1.33	1.83	1.10	0.53	0.98	1.17		1.38	0.78
S4L-m	1.04	0.47	0.86	1.07	1.42	2.54	2.61	1.66	0.59	1.11	1.07	0.77	0.73	1.32	0.61	0.62	2.81	1.14	1.56	0.94	0.46	0.84	1.00		1.18	0.67
S4M-m	0.94	0.42	0.78	0.96	1.28	2.29	2.36	1.50	0.53	1.00	0.96	0.70	0.66	1.19	0.55	0.56	2.54	1.03	1.41	0.85	0.41	0.76	0.90		1.07	0.60
S4H-m	0.91	0.41	0.76	0.94	1.25	2.23	2.30	1.46	0.52	0.98	0.94	0.68	0.64	1.16	0.54	0.54	2.47	1.00	1.38	0.83	0.40	0.74	0.88		1.04	0.59
S5L-l	1.71	0.77	1.42	1.76	2.34	4.19	4.31	2.75	0.98	1.83	1.76	1.27	1.21	2.18	1.01	1.02	4.64	1.88	2.58	1.55	0.75	1.39	1.65		1.95	1.10
S5M-l	1.52	0.68	1.26	1.56	2.08	3.72	3.83	2.44	0.87	1.63	1.56	1.13	1.07	1.94	0.90	0.90	4.11	1.67	2.29	1.37	0.67	1.23	1.47		1.73	0.98
S5H-l	1.47	0.66	1.23	1.51	2.02	3.60	3.71	2.36	0.84	1.58	1.52	1.09	1.04	1.88	0.87	0.87	3.99	1.62	2.22	1.33	0.65	1.20	1.42		1.68	0.95
C1L-m	1.01	0.46	0.84	1.04	1.39	2.48	2.55	1.62	0.58	1.08	1.04	0.75	0.71	1.29	0.60	0.60	2.74	1.11	1.53	0.92	0.44	0.82	0.98		1.16	0.65
C1M-m	0.91	0.41	0.76	0.94	1.25	2.23	2.30	1.46	0.52	0.98	0.94	0.68	0.64	1.16	0.54	0.54	2.47	1.00	1.38	0.83	0.40	0.74	0.88		1.04	0.59
C1H-m	1.16	0.52	0.96	1.19	1.58	2.83	2.91	1.86	0.66	1.24	1.19	0.86	0.82	1.47	0.68	0.69	3.13	1.27	1.74	1.05	0.51	0.94	1.12		1.32	0.74
C2L-m	0.87	0.39	0.72	0.89	1.19	2.12	2.18	1.39	0.49	0.93	0.89	0.64	0.61	1.11	0.51	0.51	2.35	0.95	1.31	0.78	0.38	0.70	0.84		0.99	0.56
C2M-m	0.70	0.32	0.58	0.72	0.96	1.72	1.77	1.13	0.40	0.75	0.72	0.52	0.50	0.90	0.41	0.42	1.90	0.77	1.06	0.64	0.31	0.57	0.68		0.80	0.45
C2H-m	0.54	0.24	0.45	0.56	0.74	1.33	1.37	0.87	0.31	0.58	0.56	0.40	0.38	0.69	0.32	0.32	1.47	0.60	0.82	0.49	0.24	0.44	0.52		0.62	0.35
C3L-l	1.84	0.83	1.53	1.90	2.52	4.51	4.65	2.96	1.05	1.98	1.90	1.37	1.30	2.35	1.09	1.09	5.00	2.03	2.78	1.67	0.81	1.50	1.78		2.11	1.18
C3M-l	1.70	0.76	1.41	1.75	2.33	4.16	4.28	2.73	0.97	1.82	1.75	1.26	1.20	2.17	1.00	1.01	4.60	1.87	2.56	1.54	0.75	1.38	1.64		1.94	1.09
C3H-l	1.69	0.76	1.40	1.73	2.31	4.12	4.25	2.70	0.96	1.81	1.73	1.25	1.19	2.15	0.99	1.00	4.57	1.85	2.54	1.53	0.74	1.37	1.63		1.92	1.08
PC1-m	1.08	0.49	0.90	1.11	1.48	2.65	2.73	1.74	0.62	1.16	1.12	0.80	0.76	1.38	0.64	0.64	2.94	1.19	1.63	0.98	0.48	0.88	1.05		1.24	0.70
PC2L-m	1.03	0.46	0.86	1.06	1.41	2.52	2.60	1.65	0.59	1.10	1.06	0.77	0.73	1.31	0.61	0.61	2.79	1.13	1.55	0.93	0.45	0.84	0.99		1.18	0.66
PC2M-m	0.93	0.42	0.77	0.95	1.27	2.27	2.34	1.49	0.53	0.99	0.95	0.69	0.65	1.18	0.55	0.55	2.51	1.02	1.40	0.84	0.41	0.75	0.89		1.06	0.60
PC2H-m	0.92	0.42	0.77	0.95	1.27	2.26	2.33	1.48	0.53	0.99	0.95	0.69	0.65	1.18	0.55	0.55	2.51	1.02	1.39	0.84	0.41	0.75	0.89		1.06	0.59
RM1L-m	0.95	0.43	0.79	0.98	1.30	2.33	2.40	1.53	0.54	1.02	0.98	0.71	0.67	1.22	0.56	0.57	2.58	1.05	1.44	0.86	0.42	0.77	0.92		1.09	0.61
RM1M-m	0.79	0.35	0.65	0.81	1.08	1.92	1.98	1.26	0.45	0.84	0.81	0.58	0.55	1.00	0.46	0.47	2.13	0.86	1.18	0.71	0.34	0.64	0.76		0.90	0.50
RM2L-m	0.94	0.42	0.79	0.97	1.29	2.31	2.38	1.51	0.54	1.01	0.97	0.70	0.67	1.20	0.56	0.56	2.56	1.04	1.42	0.85	0.41	0.77	0.91		1.08	0.61
RM2M-m	0.78	0.35	0.65	0.80	1.07	1.91	1.97	1.25	0.45	0.84	0.80	0.58	0.55	1.00	0.46	0.46	2.12	0.86	1.18	0.71	0.34	0.63	0.75		0.89	0.50
RM2H-m	0.82	0.37	0.68	0.84	1.12	2.00	2.06	1.31	0.47	0.88	0.84	0.61	0.58	1.04	0.48	0.49	2.22	0.90	1.23	0.74	0.36	0.66	0.79		0.93	0.53
URML-l	1.80	0.81	1.49	1.85	2.46	4.40	4.53	2.88	1.02	1.93	1.85	1.33	1.27	2.29	1.06	1.07	4.87	1.97	2.71	1.63	0.79	1.46	1.73		2.05	1.15
URMM-l	1.73	0.78	1.44	1.78	2.37	4.24	4.37	2.78	0.99	1.86	1.79	1.29	1.22	2.21	1.02	1.03	4.70	1.90	2.62	1.57	0.76	1.41	1.67		1.98	1.11
Mean	1.09	0.49	0.90	1.12	1.49	2.66	2.74	1.74	0.62	1.16	1.12	0.81	0.77	1.38	0.64	0.64	2.94	1.19	1.64	0.98	0.48	0.88	1.05		1.24	
Std. Dev.	0.37	0.16	0.30	0.38	0.50	0.89	0.92	0.59	0.21	0.39	0.38	0.27	0.26	0.47	0.22	0.22	0.99	0.40	0.55	0.33	0.16	0.30	0.35			0.83

Table 19. Discrepancy factor given S_{M1}-level shaking for MCE_R high-seismicity locations

Discrepancy Factor Based on S_{M1}-Level Shaking in MCE_R Locations (D')																										
Building Type	PNW1	PNW2	PNW3	NorCal 1	NorCal2	NorCal3	SoCal1	SoCal2	SoCal3	SoCal4	SoCal5	SoCal6	SoCal7	Utah1	Utah2	NMad1	NMad2	NMad3	SC1	SC2	NY1	PR1	AK1		Mean Value	Standard Deviation
W1-m	0.63	0.29	0.49	0.64	0.65	1.34	1.25	0.91	0.40	0.78	0.70	0.51	0.48	0.71	0.36	0.34	1.38	0.60	0.83	0.50	0.26	0.52	0.58		0.66	0.31
W2-m	0.74	0.34	0.57	0.76	0.76	1.58	1.47	1.07	0.47	0.91	0.83	0.60	0.56	0.83	0.42	0.40	1.62	0.71	0.98	0.59	0.31	0.61	0.68		0.77	0.37
S1L-m	1.14	0.53	0.88	1.16	1.17	2.42	2.26	1.65	0.72	1.40	1.27	0.92	0.87	1.28	0.64	0.62	2.49	1.09	1.50	0.91	0.47	0.93	1.04		1.19	0.56
S1M-m	1.20	0.56	0.93	1.23	1.24	2.56	2.38	1.73	0.76	1.48	1.34	0.97	0.91	1.35	0.68	0.65	2.63	1.15	1.58	0.96	0.50	0.98	1.10		1.26	0.59
S1H-m	1.32	0.61	1.02	1.35	1.36	2.81	2.62	1.91	0.84	1.62	1.47	1.07	1.00	1.49	0.75	0.71	2.89	1.27	1.74	1.05	0.55	1.08	1.21		1.38	0.65
S2L-m	1.12	0.52	0.86	1.14	1.15	2.37	2.20	1.61	0.70	1.37	1.24	0.90	0.85	1.25	0.63	0.60	2.43	1.07	1.46	0.89	0.46	0.91	1.02		1.16	0.55
S2M-m	1.00	0.46	0.77	1.02	1.03	2.12	1.98	1.44	0.63	1.23	1.11	0.81	0.76	1.12	0.56	0.54	2.18	0.96	1.31	0.79	0.41	0.82	0.91		1.04	0.49
S2H-m	1.02	0.47	0.79	1.04	1.05	2.16	2.01	1.47	0.64	1.25	1.13	0.82	0.77	1.14	0.57	0.55	2.22	0.97	1.34	0.81	0.42	0.83	0.93		1.06	0.50
S3-m	1.41	0.66	1.09	1.44	1.45	3.00	2.80	2.04	0.89	1.74	1.57	1.14	1.07	1.59	0.80	0.76	3.09	1.35	1.85	1.12	0.58	1.15	1.29		1.47	0.70
S4L-m	1.21	0.56	0.93	1.23	1.25	2.57	2.40	1.74	0.77	1.49	1.35	0.98	0.92	1.36	0.68	0.65	2.64	1.16	1.59	0.96	0.50	0.99	1.10		1.26	0.60
S4M-m	1.09	0.51	0.84	1.11	1.12	2.32	2.16	1.57	0.69	1.34	1.22	0.88	0.83	1.23	0.62	0.59	2.39	1.05	1.43	0.87	0.45	0.89	1.00		1.14	0.54
S4H-m	1.07	0.49	0.82	1.09	1.10	2.26	2.11	1.53	0.67	1.31	1.18	0.86	0.81	1.20	0.60	0.57	2.33	1.02	1.40	0.85	0.44	0.87	0.97		1.11	0.53
S5L-l	2.00	0.93	1.54	2.04	2.06	4.24	3.95	2.88	1.26	2.45	2.22	1.61	1.52	2.24	1.13	1.08	4.36	1.91	2.62	1.59	0.83	1.63	1.82		2.08	0.99
S5M-l	1.77	0.82	1.37	1.81	1.82	3.76	3.51	2.55	1.12	2.18	1.97	1.43	1.35	1.99	1.00	0.96	3.87	1.70	2.33	1.41	0.73	1.45	1.62		1.85	0.87
S5H-l	1.72	0.80	1.33	1.75	1.77	3.65	3.40	2.48	1.09	2.11	1.91	1.39	1.31	1.93	0.97	0.93	3.75	1.65	2.26	1.37	0.71	1.40	1.57		1.79	0.85
C1L-m	1.18	0.55	0.91	1.21	1.22	2.51	2.34	1.70	0.75	1.45	1.31	0.96	0.90	1.33	0.67	0.64	2.58	1.13	1.55	0.94	0.49	0.96	1.08		1.23	0.58
C1M-m	1.07	0.49	0.82	1.09	1.10	2.26	2.11	1.53	0.67	1.31	1.18	0.86	0.81	1.20	0.60	0.57	2.32	1.02	1.40	0.85	0.44	0.87	0.97		1.11	0.53
C1H-m	1.35	0.63	1.04	1.38	1.39	2.87	2.67	1.95	0.85	1.66	1.50	1.09	1.03	1.52	0.76	0.73	2.95	1.29	1.77	1.07	0.56	1.10	1.23		1.41	0.67
C2L-m	1.01	0.47	0.78	1.03	1.04	2.15	2.00	1.46	0.64	1.24	1.13	0.82	0.77	1.14	0.57	0.55	2.21	0.97	1.33	0.80	0.42	0.83	0.92		1.06	0.50
C2M-m	0.82	0.38	0.63	0.84	0.84	1.74	1.62	1.18	0.52	1.01	0.91	0.66	0.62	0.92	0.46	0.44	1.79	0.78	1.08	0.65	0.34	0.67	0.75		0.85	0.40
C2H-m	0.63	0.29	0.49	0.65	0.65	1.35	1.25	0.91	0.40	0.78	0.71	0.51	0.48	0.71	0.36	0.34	1.38	0.61	0.83	0.50	0.26	0.52	0.58		0.66	0.31
C3L-l	2.15	1.00	1.66	2.20	2.21	4.57	4.26	3.10	1.36	2.64	2.39	1.74	1.64	2.42	1.21	1.16	4.70	2.06	2.83	1.71	0.89	1.76	1.96		2.25	1.06
C3M-l	1.98	0.92	1.53	2.02	2.04	4.21	3.92	2.86	1.25	2.44	2.21	1.60	1.51	2.23	1.12	1.07	4.33	1.90	2.60	1.58	0.82	1.62	1.81		2.07	0.98
C3H-l	1.97	0.91	1.52	2.01	2.02	4.18	3.89	2.83	1.24	2.42	2.19	1.59	1.49	2.21	1.11	1.06	4.30	1.88	2.58	1.56	0.81	1.61	1.80		2.05	0.97
PC1-m	1.27	0.59	0.98	1.29	1.30	2.69	2.50	1.82	0.80	1.55	1.41	1.02	0.96	1.42	0.71	0.68	2.76	1.21	1.66	1.01	0.52	1.03	1.15		1.32	0.62
PC2L-m	1.20	0.56	0.93	1.23	1.24	2.55	2.38	1.73	0.76	1.48	1.34	0.97	0.91	1.35	0.68	0.65	2.63	1.15	1.58	0.96	0.50	0.98	1.10		1.25	0.59
PC2M-m	1.08	0.50	0.84	1.10	1.11	2.30	2.14	1.56	0.68	1.33	1.20	0.87	0.82	1.22	0.61	0.58	2.36	1.04	1.42	0.86	0.45	0.88	0.99		1.13	0.53
PC2H-m	1.08	0.50	0.83	1.10	1.11	2.29	2.14	1.56	0.68	1.33	1.20	0.87	0.82	1.21	0.61	0.58	2.36	1.03	1.42	0.86	0.45	0.88	0.99		1.13	0.53
RM1L-m	1.11	0.52	0.86	1.13	1.14	2.36	2.20	1.60	0.70	1.37	1.24	0.90	0.84	1.25	0.63	0.60	2.43	1.07	1.46	0.88	0.46	0.91	1.02		1.16	0.55
RM1M-m	0.92	0.43	0.71	0.94	0.94	1.95	1.81	1.32	0.58	1.13	1.02	0.74	0.70	1.03	0.52	0.49	2.00	0.88	1.20	0.73	0.38	0.75	0.84		0.96	0.45
RM2L-m	1.10	0.51	0.85	1.12	1.13	2.34	2.18	1.59	0.70	1.35	1.23	0.89	0.84	1.24	0.62	0.59	2.41	1.06	1.45	0.88	0.46	0.90	1.01		1.15	0.54
RM2M-m	0.91	0.42	0.70	0.93	0.94	1.94	1.80	1.31	0.58	1.12	1.01	0.74	0.69	1.02	0.51	0.49	1.99	0.87	1.20	0.72	0.38	0.74	0.83		0.95	0.45
RM2H-m	0.96	0.44	0.74	0.97	0.98	2.03	1.89	1.38	0.60	1.17	1.06	0.77	0.73	1.07	0.54	0.52	2.08	0.91	1.25	0.76	0.39	0.78	0.87		1.00	0.47
URML-l	2.10	0.97	1.62	2.14	2.16	4.45	4.15	3.02	1.33	2.58	2.33	1.70	1.59	2.36	1.18	1.13	4.58	2.01	2.75	1.67	0.87	1.71	1.91		2.19	1.03
URMM-l	2.03	0.94	1.56	2.07	2.08	4.30	4.01	2.92	1.28	2.49	2.25	1.64	1.54	2.27	1.14	1.09	4.42	1.94	2.66	1.61	0.84	1.65	1.85		2.11	1.00
Mean	1.27	0.59	0.98	1.29	1.30	2.69	2.51	1.83	0.80	1.56	1.41	1.02	0.96	1.42	0.71	0.68	2.77	1.21	1.66	1.01	0.52	1.04	1.16		1.32	
Std. Dev.	0.43	0.20	0.33	0.44	0.44	0.91	0.84	0.61	0.27	0.52	0.47	0.34	0.32	0.48	0.24	0.23	0.93	0.41	0.56	0.34	0.18	0.35	0.39			0.78

Moderate-Seismicity Locations

Shear Wave Velocities & Soil Site Classifications

The shear wave velocities provided in meters per second by the USGS mapping tool for all moderate-seismicity locations are shown in Table 20. Also included in these tables are the converted shear wave velocities in feet per second and their corresponding site classifications.

Table 20. Shear wave and site class data for moderate-seismicity locations

Moderate Seismicity			
Location	V_{s30} (m/s)	V_{s30} (ft/s)	Site Class
Portland 1	760	2493	B
Sacramento 1	456	1496	C
Spokane 1	442	1450	C
Boise 1	258	846	D
Las Vegas 1	287	942	D
Phoenix 1	380	1247	C
Albuquerque 1	186	610	D
El Paso 1	536	1759	C
Denver 1	549	1801	C
Oklahoma City 1	222	728	D
Kansas City 1	375	1230	C
St. Louis 1	306	1004	D
Urbana 1	248	814	D
Nashville 1	315	1033	D
Indianapolis 1	207	679	D
Louisville 1	302	991	D
Atlanta 1	285	935	D
Charlotte 1	281	922	D
Philadelphia 1	281	922	D
New York 1	506	1660	C
Boston 1	371	1217	C

Design Shaking Values

Table 21 presents the S_1-, F_v-, S_{M1}-, and S_{D1}-values for all moderate-seismicity locations based on MCE shaking. Similarly, Table 22 presents the S_1-, F_v-, S_{M1}-, and S_{D1}-values for all moderate-seismicity locations based on MCE_R shaking.

Table 21. S_1-, F_v-, S_{M1}-, and S_{D1}-values for moderate-seismicity locations subjected to MCE shaking

MCE				
Moderate Seismicity				
Location	S_1 (g)	F_v	S_{M1} (g)	S_{D1} (g)
Portland 1	0.223	1.00	0.223	0.149
Sacramento 1	0.148	1.65	0.245	0.163
Spokane 1	0.097	1.70	0.165	0.110
Boise 1	0.083	2.40	0.199	0.133
Las Vegas 1	0.128	2.29	0.292	0.195
Phoenix 1	0.066	1.70	0.112	0.075
Albuquerque 1	0.119	2.32	0.276	0.184
El Paso 1	0.087	1.70	0.148	0.099
Denver 1	0.063	1.70	0.108	0.072
Oklahoma City 1	0.068	2.40	0.163	0.109
Kansas City 1	0.058	1.70	0.098	0.065
St. Louis 1	0.122	2.31	0.282	0.188
Urbana 1	0.087	2.40	0.210	0.140
Nashville 1	0.119	2.32	0.277	0.185
Indianapolis 1	0.076	2.40	0.182	0.122
Louisville 1	0.093	2.40	0.223	0.149
Atlanta 1	0.077	2.40	0.186	0.124
Charlotte 1	0.093	2.40	0.222	0.148
Philadelphia 1	0.052	2.40	0.125	0.083
New York 1	0.062	1.70	0.106	0.070
Boston 1	0.062	1.70	0.106	0.071

Table 22. S_1-, F_v-, S_{M1}-, and S_{D1}-values for moderate-seismicity locations subjected to MCER shaking

MCE$_R$				
Moderate Seismicity				
Location	S_1 (g)	F_v	S_{M1} (g)	S_{D1} (g)
Portland 1	0.254	1.00	0.254	0.169
Sacramento 1	0.223	1.58	0.351	0.234
Spokane 1	0.115	1.69	0.193	0.129
Boise 1	0.104	2.38	0.248	0.166
Las Vegas 1	0.164	2.14	0.352	0.234
Phoenix 1	0.079	1.70	0.134	0.090
Albuquerque 1	0.137	2.25	0.308	0.205
El Paso 1	0.113	1.69	0.191	0.128
Denver 1	0.073	1.70	0.124	0.083
Oklahoma City 1	0.078	2.40	0.186	0.124
Kansas City 1	0.064	1.70	0.108	0.072
St. Louis 1	0.132	2.27	0.300	0.200
Urbana 1	0.096	2.40	0.230	0.153
Nashville 1	0.131	2.28	0.298	0.199
Indianapolis 1	0.085	2.40	0.204	0.136
Louisville 1	0.103	2.39	0.246	0.164
Atlanta 1	0.090	2.40	0.216	0.144
Charlotte 1	0.104	2.39	0.247	0.165
Philadelphia 1	0.061	2.40	0.146	0.097
New York 1	0.072	1.70	0.123	0.082
Boston 1	0.072	1.70	0.123	0.082

Hazard Curves

Figure 11 shows the hazard curves for each of the moderate-seismicity locations. This plot uses a logarithmic scale on the y-axis to show where the curves intersect major annual exceedance probabilities. This plot also includes a black dashed line, which represents the 2% in 50 years probability of exceedance previously used to determine MCE design-level shaking.

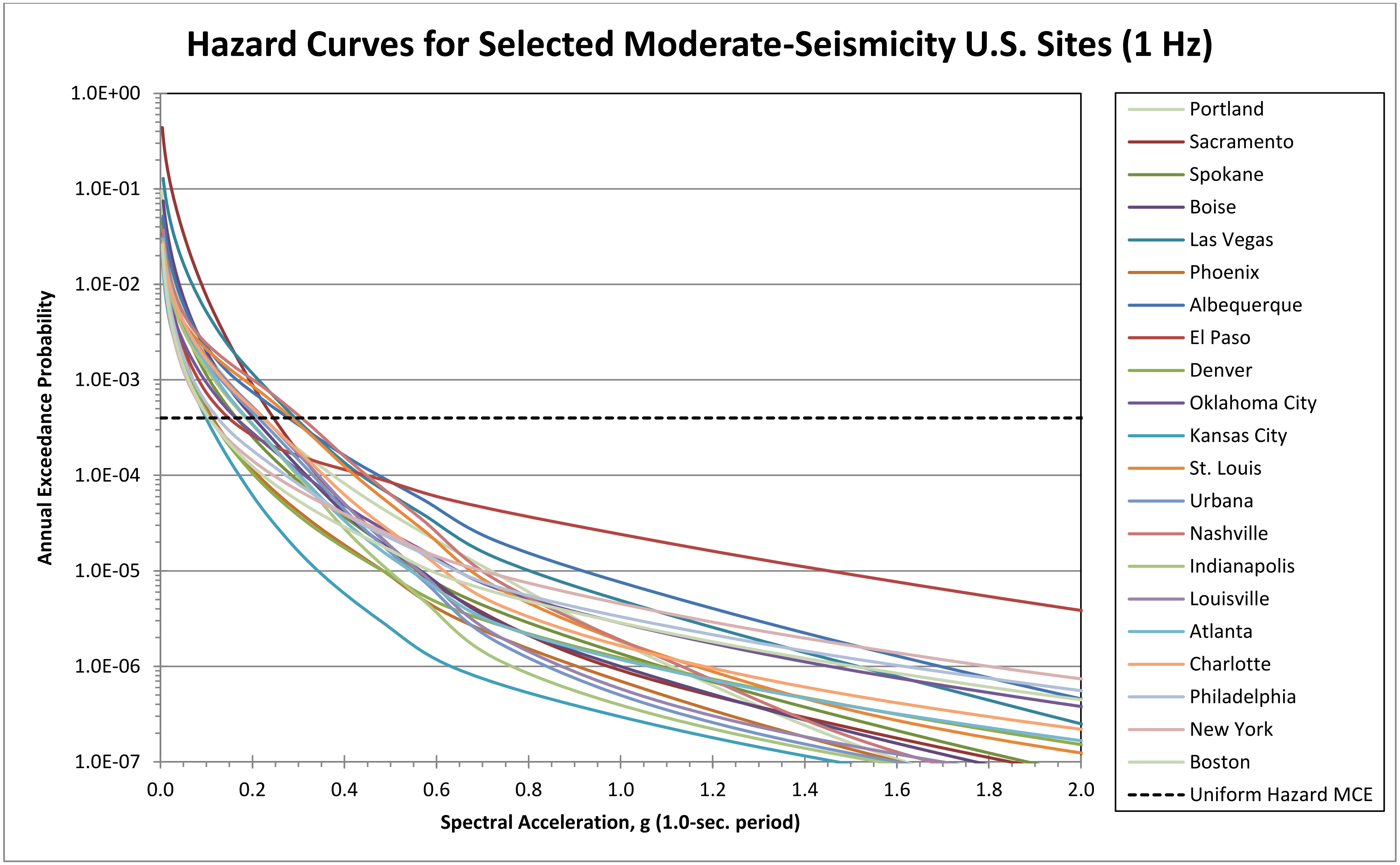

Figure 11. Hazard curves for all moderate-seismicity locations

Provided Fragility Curve Data – Low Code

Figures 12 - 14 show a sample set of fragility curve data points from HAZUS-MH for a concrete moment frame lowrise, midrise, and highrise building, respectively, subjected to low code. Figure 15 presents a comparison among all three height-specific fragility curve datasets for a concrete moment frame building subjected to low code.

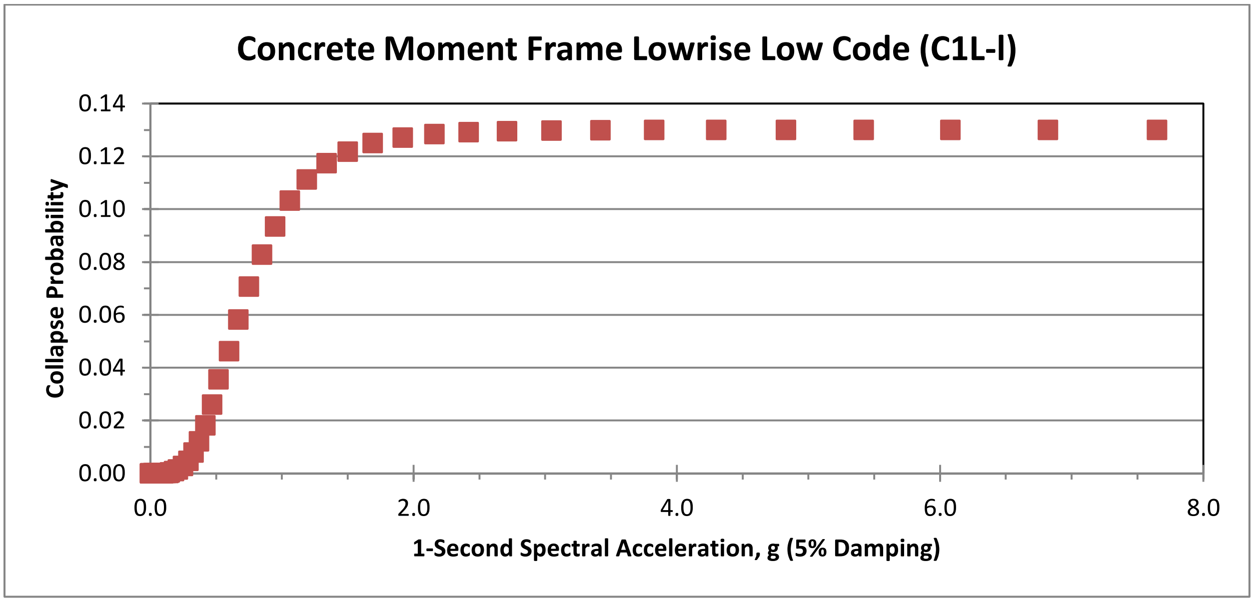

Figure 12. Fragility data for an existing lowrise concrete moment frame building subjected to low code

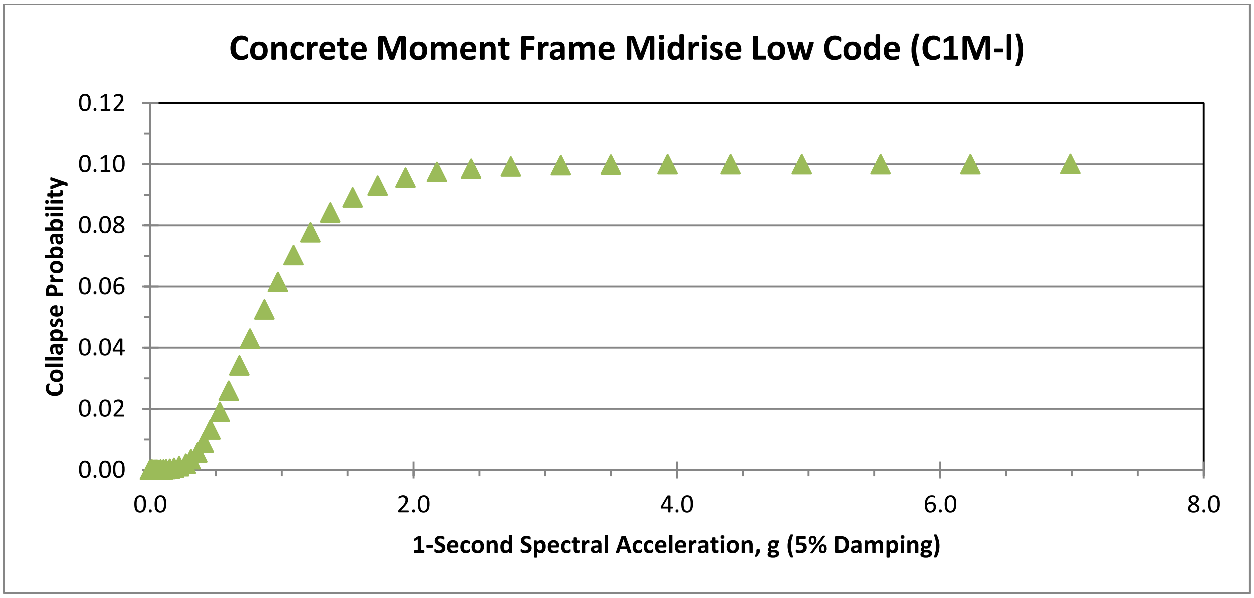

Figure 13. Fragility data for an existing midrise concrete moment frame building subjected to low code

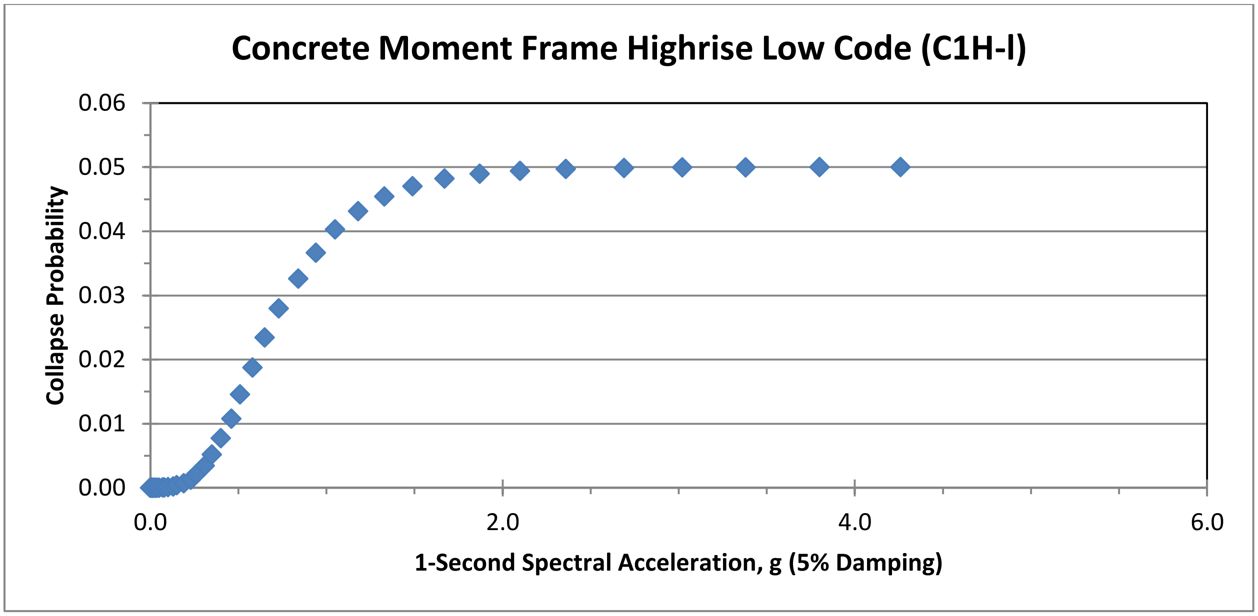

Figure 14. Fragility data for an existing highrise concrete moment frame building subjected to low code

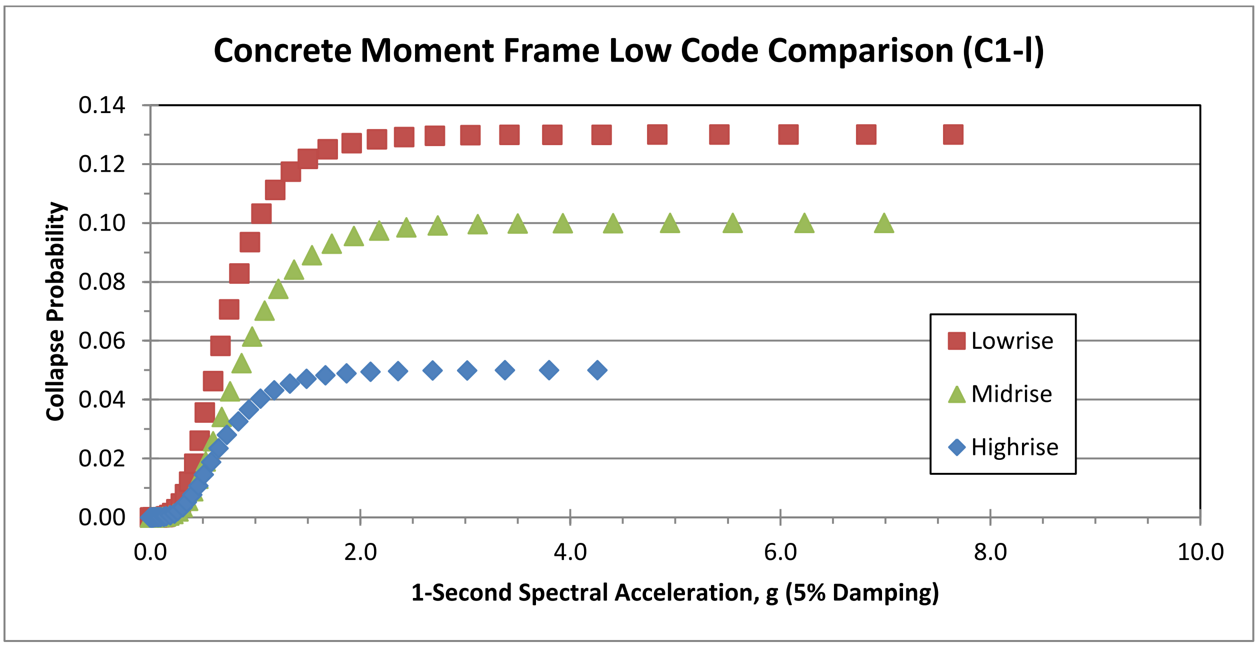

Figure 15. Fragility data comparison for existing lowrise, midrise, and highrise concrete moment frame buildings subjected to low code

Fitted Lognormal Curves – Low Code

Figures 16 - 18 present graphical comparisons of the normalized fragility data provided by HAZUS-MH and their corresponding fitted lognormal curves. The figures are again specific to a lowrise, midrise, and highrise concrete moment frame building subjected to low code.

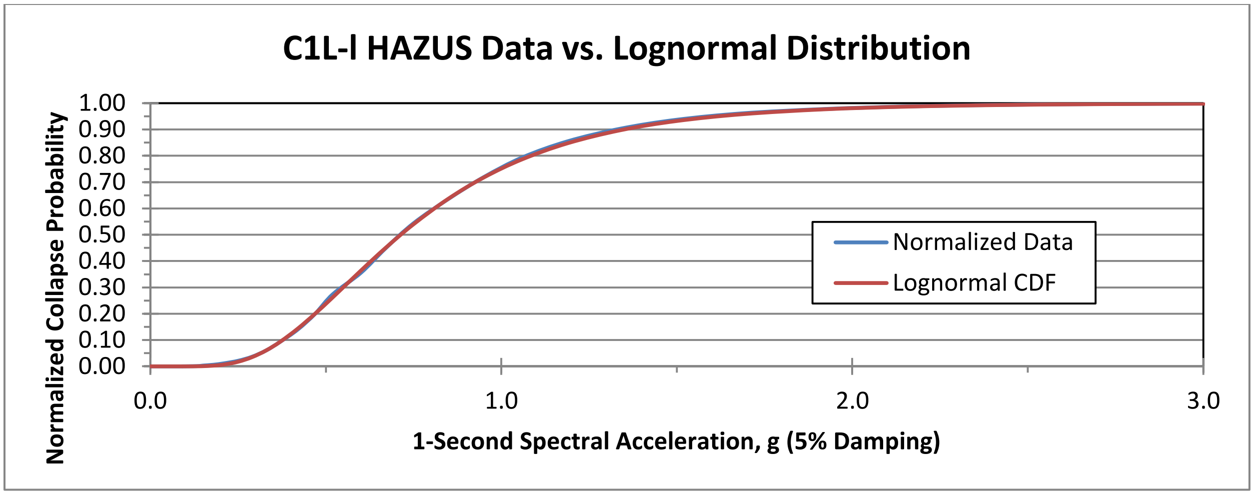

Figure 16. Fitted lognormal curve to data from lowrise concrete moment frame building subjected to low code

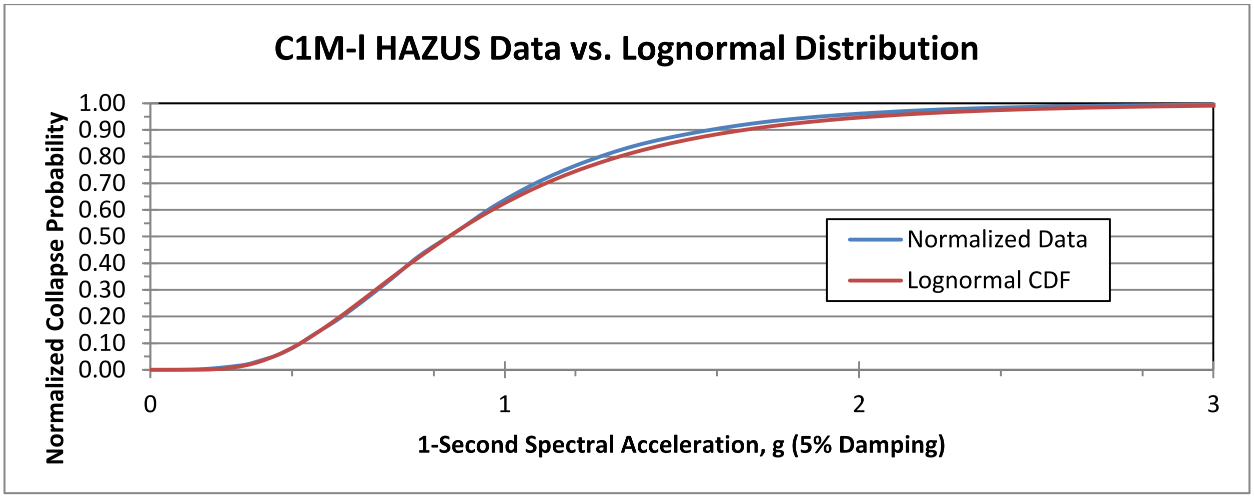

Figure 17. Fitted lognormal curve to data from midrise concrete moment frame building subjected to low code

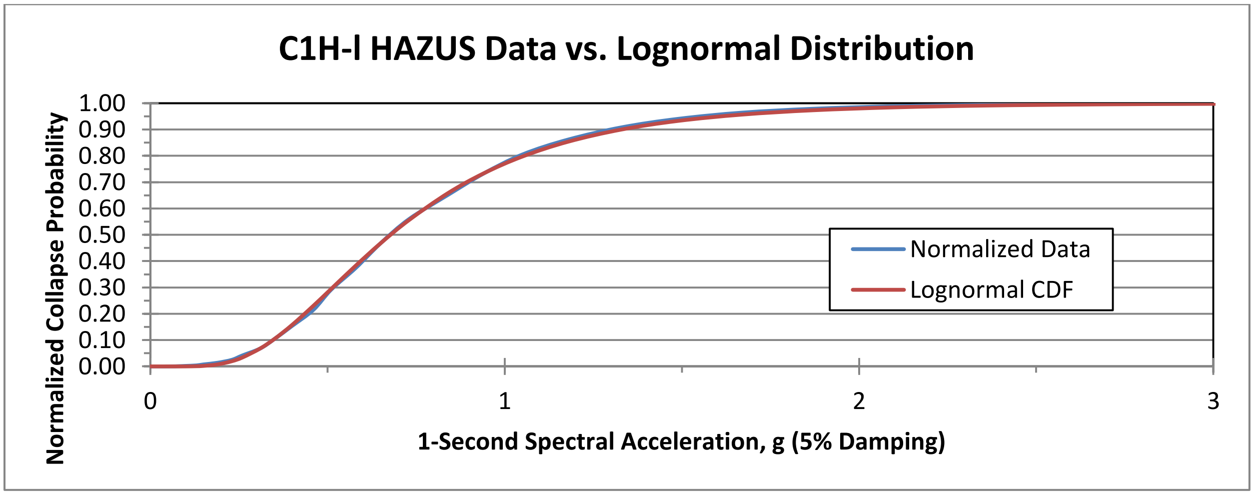

Figure 18. Fitted lognormal curve to data from highrise concrete moment frame building subjected to low code

Kolmogorov-Smirnov Goodness-of-Fit Test – Low Code

Table 23 presents the median collapse capacities, log-standard deviations, number of data points, critical K.S. statistic values, and actual K.S. statistics for all low-code building types.

Table 23. Median collapse capacities, logarithmic standard deviations, number of data points, criticial K.S. statistics, and actual K.S. statistics for low code building types

CDF Data Comparisons						
Building Type	Median Collapse Capacity, Θ (g)	Log. Standard Deviation, β	# of Data Points, n	95% Critical Standard K.S. Statistic	95% Critical Adjusted K.S. Statistic	K.S. Statistic
W1-l	1.595	0.537	51	0.190	0.124	0.017
W2-l	1.263	0.507	51	0.190	0.124	0.006
S1L-l	0.833	0.499	47	0.198	0.129	0.012
S1M-l	0.839	0.532	44	0.205	0.134	0.014
S1H-l	0.813	0.530	42	0.210	0.137	0.021
S2L-l	0.863	0.507	51	0.190	0.124	0.011
S2M-l	1.000	0.533	45	0.203	0.132	0.014
S2H-l	1.072	0.552	42	0.210	0.137	0.035
S3-l	0.638	0.481	51	0.190	0.124	0.019
S4L-l	0.767	0.502	51	0.190	0.124	0.011
S4M-l	0.896	0.517	47	0.198	0.129	0.010
S4H-l	0.970	0.541	44	0.205	0.134	0.021
S5L-l	0.723	0.497	51	0.190	0.124	0.015
S5M-l	0.850	0.529	48	0.196	0.128	0.018
S5H-l	0.892	0.543	44	0.205	0.134	0.016
C1L-l	0.713	0.497	51	0.190	0.124	0.012
C1M-l	0.842	0.537	46	0.201	0.131	0.024
C1H-l	0.678	0.525	44	0.205	0.134	0.016
C2L-l	0.829	0.507	50	0.192	0.125	0.017
C2M-l	0.972	0.529	48	0.196	0.128	0.018
C2H-l	1.007	0.524	45	0.203	0.132	0.019
C3L-l	0.660	0.484	51	0.190	0.124	0.017
C3M-l	0.763	0.532	50	0.192	0.125	0.016
C3H-l	0.799	0.562	46	0.201	0.131	0.032
PC1-l	0.733	0.485	51	0.190	0.124	0.021
PC2L-l	0.687	0.497	51	0.190	0.124	0.009
PC2M-l	0.817	0.536	48	0.196	0.128	0.020
PC2H-l	0.837	0.546	45	0.203	0.132	0.018
RM1L-l	0.807	0.472	51	0.190	0.124	0.013
RM1M-l	0.958	0.511	51	0.190	0.124	0.012
RM2L-l	0.807	0.464	51	0.190	0.124	0.013
RM2M-l	0.958	0.511	50	0.192	0.125	0.012
RM2H-l	0.982	0.539	45	0.203	0.132	0.020
URML-l	0.759	0.572	51	0.190	0.124	0.016
URMM-l	0.709	0.491	51	0.190	0.124	0.013
Average	0.867	0.518	48.143	0.196	0.128	0.016

Further Data Collection – Low Code

Tables 24 and 25 provide the probabilities of collapse based on MCE design-level shaking and MCE_R design-level shaking, respectively (S_{D1}-values for MCE and MCE_R). These probabilities are signified by P_{MCE} and P_{MCER}, respectively. Table 26 shows the annual frequencies of collapse calculated via the risk integral, and represented by λ. Tables 27 - 29 show the resulting scores for each building type in each location calculated from P_{MCE}, P_{MCER}, and λ, respectively. Tables 30 and 31 provide the performance modification factors, represented by PMF and PMF', for each building type in each location. Finally, Tables 32 and 33 show the discrepancy values, signified by D and D', for each scenario.

Table 24. Probability of collapse given S_{D1}-level shaking in MCE moderate-seismicity locations

Probability of Collapse Given S_{D1}-Level Shaking in MCE Moderate-Seismicity Locations (P_{MCE})																								
Building Type	Portland1	Sacramento1	Spokane1	Boise1	Las Vegas1	Phoenix1	Albequerque1	El Paso1	Denver1	OKC1	Kansas City1	St. Louis1	Urbana1	Nashville 1	Indianapolis1	Louisville 1	Atlanta1	Charlotte 1	Philadelphia1	New York1	Boston1		Mean Value	Standard Deviation
W1-l	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
W2-l	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
S1L-l	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
S1M-l	0.00%	0.01%	0.00%	0.00%	0.02%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
S1H-l	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
S2L-l	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
S2M-l	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
S2H-l	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
S3-l	0.00%	0.01%	0.00%	0.00%	0.02%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.01%
S4L-l	0.00%	0.01%	0.00%	0.00%	0.03%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.01%	0.01%
S4M-l	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
S4H-l	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
S5L-l	0.01%	0.01%	0.00%	0.00%	0.03%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.02%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.01%	0.01%
S5M-l	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
S5H-l	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
C1L-l	0.01%	0.02%	0.00%	0.00%	0.06%	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.05%	0.01%	0.04%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.01%	0.02%
C1M-l	0.01%	0.01%	0.00%	0.00%	0.03%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.02%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.01%	0.01%
C1H-l	0.01%	0.02%	0.00%	0.00%	0.04%	0.00%	0.03%	0.00%	0.00%	0.00%	0.00%	0.04%	0.01%	0.03%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.01%	0.01%
C2L-l	0.00%	0.01%	0.00%	0.00%	0.03%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.01%	0.01%
C2M-l	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
C2H-l	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
C3L-l	0.02%	0.03%	0.00%	0.01%	0.09%	0.00%	0.06%	0.00%	0.00%	0.00%	0.00%	0.07%	0.01%	0.06%	0.00%	0.02%	0.00%	0.02%	0.00%	0.00%	0.00%		0.02%	0.03%
C3M-l	0.01%	0.02%	0.00%	0.01%	0.07%	0.00%	0.05%	0.00%	0.00%	0.00%	0.00%	0.06%	0.01%	0.05%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.02%	0.02%
C3H-l	0.01%	0.01%	0.00%	0.00%	0.03%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.03%	0.00%	0.02%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.01%	0.01%
PC1-l	0.01%	0.01%	0.00%	0.00%	0.05%	0.00%	0.03%	0.00%	0.00%	0.00%	0.00%	0.04%	0.00%	0.03%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.01%	0.01%
PC2L-l	0.02%	0.03%	0.00%	0.01%	0.08%	0.00%	0.06%	0.00%	0.00%	0.00%	0.00%	0.07%	0.01%	0.06%	0.00%	0.02%	0.00%	0.02%	0.00%	0.00%	0.00%		0.02%	0.03%
PC2M-l	0.01%	0.02%	0.00%	0.00%	0.05%	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.04%	0.01%	0.04%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.01%	0.02%
PC2H-l	0.01%	0.01%	0.00%	0.00%	0.04%	0.00%	0.03%	0.00%	0.00%	0.00%	0.00%	0.03%	0.01%	0.03%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.01%	0.01%
RM1L-l	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.01%
RM1M-l	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
RM2L-l	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
RM2M-l	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
RM2H-l	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
URML-l	0.03%	0.05%	0.01%	0.02%	0.13%	0.00%	0.10%	0.00%	0.00%	0.01%	0.00%	0.11%	0.02%	0.10%	0.01%	0.03%	0.01%	0.03%	0.00%	0.00%	0.00%		0.03%	0.04%
URMM-l	0.01%	0.02%	0.00%	0.00%	0.06%	0.00%	0.05%	0.00%	0.00%	0.00%	0.00%	0.05%	0.01%	0.05%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.01%	0.02%
Mean	0.01%	0.01%	0.00%	0.00%	0.03%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.02%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.01%	
Std. Dev.	0.01%	0.01%	0.00%	0.00%	0.03%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.02%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%			0.01%

Table 25. Probability of collapse given S_{D1}-level shaking in MCE_R moderate-seismicity locations

Probability of Collapse Given S_{D1}-Level Shaking in MCE_R Moderate-Seismicity Locations (P_{MCER})																								
Building Type	Portland1	Sacramento1	Spokane1	Boise1	Las Vegas1	Phoenix1	Albuquerque1	El Paso1	Denver1	OKC1	Kansas City1	St. Louis1	Urbana1	Nashville 1	Indianapolis1	Louisville 1	Atlanta1	Charlotte 1	Philadelphia1	New York1	Boston1		Mean Value	Standard Deviation
W1-l	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
W2-l	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
S1L-l	0.01%	0.04%	0.00%	0.00%	0.04%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.01%	0.01%
S1M-l	0.01%	0.04%	0.00%	0.01%	0.04%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.02%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.01%	0.01%
S1H-l	0.00%	0.03%	0.00%	0.00%	0.03%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.01%	0.01%
S2L-l	0.01%	0.04%	0.00%	0.00%	0.04%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.01%	0.01%
S2M-l	0.00%	0.02%	0.00%	0.00%	0.02%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
S2H-l	0.00%	0.01%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
S3-l	0.01%	0.06%	0.00%	0.01%	0.06%	0.00%	0.03%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.02%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.01%	0.02%
S4L-l	0.01%	0.07%	0.00%	0.01%	0.07%	0.00%	0.03%	0.00%	0.00%	0.00%	0.00%	0.03%	0.01%	0.03%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.01%	0.02%
S4M-l	0.00%	0.02%	0.00%	0.00%	0.02%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.01%
S4H-l	0.00%	0.01%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
S5L-l	0.01%	0.09%	0.00%	0.01%	0.09%	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.04%	0.01%	0.04%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.02%	0.03%
S5M-l	0.01%	0.04%	0.00%	0.00%	0.04%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.01%	0.01%
S5H-l	0.00%	0.02%	0.00%	0.00%	0.02%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.01%
C1L-l	0.03%	0.16%	0.00%	0.02%	0.16%	0.00%	0.08%	0.00%	0.00%	0.00%	0.00%	0.07%	0.01%	0.07%	0.01%	0.02%	0.01%	0.02%	0.00%	0.00%	0.00%		0.03%	0.05%
C1M-l	0.01%	0.09%	0.00%	0.01%	0.09%	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.04%	0.01%	0.04%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.02%	0.03%
C1H-l	0.02%	0.11%	0.00%	0.02%	0.11%	0.00%	0.06%	0.00%	0.00%	0.00%	0.00%	0.05%	0.01%	0.05%	0.01%	0.02%	0.01%	0.02%	0.00%	0.00%	0.00%		0.02%	0.03%
C2L-l	0.01%	0.08%	0.00%	0.01%	0.08%	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.03%	0.01%	0.03%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.02%	0.02%
C2M-l	0.00%	0.04%	0.00%	0.00%	0.04%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.01%	0.01%
C2H-l	0.00%	0.01%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.00%
C3L-l	0.04%	0.24%	0.01%	0.03%	0.24%	0.00%	0.12%	0.01%	0.00%	0.00%	0.00%	0.10%	0.02%	0.10%	0.01%	0.03%	0.01%	0.03%	0.00%	0.00%	0.00%		0.05%	0.07%
C3M-l	0.03%	0.17%	0.01%	0.03%	0.17%	0.00%	0.09%	0.01%	0.00%	0.00%	0.00%	0.08%	0.02%	0.07%	0.01%	0.03%	0.01%	0.03%	0.00%	0.00%	0.00%		0.04%	0.05%
C3H-l	0.01%	0.07%	0.00%	0.01%	0.07%	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.03%	0.01%	0.03%	0.00%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%		0.02%	0.02%
PC1-l	0.02%	0.14%	0.00%	0.02%	0.14%	0.00%	0.06%	0.00%	0.00%	0.00%	0.00%	0.06%	0.01%	0.05%	0.00%	0.02%	0.01%	0.02%	0.00%	0.00%	0.00%		0.03%	0.04%
PC2L-l	0.04%	0.23%	0.01%	0.03%	0.23%	0.00%	0.11%	0.01%	0.00%	0.00%	0.00%	0.10%	0.02%	0.09%	0.01%	0.03%	0.01%	0.03%	0.00%	0.00%	0.00%		0.05%	0.07%
PC2M-l	0.02%	0.13%	0.00%	0.02%	0.13%	0.00%	0.06%	0.00%	0.00%	0.00%	0.00%	0.06%	0.01%	0.05%	0.01%	0.02%	0.01%	0.02%	0.00%	0.00%	0.00%		0.03%	0.04%
PC2H-l	0.02%	0.10%	0.00%	0.01%	0.10%	0.00%	0.05%	0.00%	0.00%	0.00%	0.00%	0.04%	0.01%	0.04%	0.00%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%		0.02%	0.03%
RM1L-l	0.01%	0.06%	0.00%	0.01%	0.06%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.01%	0.02%
RM1M-l	0.00%	0.03%	0.00%	0.00%	0.03%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.01%	0.01%
RM2L-l	0.01%	0.05%	0.00%	0.00%	0.05%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.02%	0.00%	0.02%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.01%	0.02%
RM2M-l	0.00%	0.03%	0.00%	0.00%	0.03%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.01%	0.01%
RM2H-l	0.00%	0.02%	0.00%	0.00%	0.02%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%		0.00%	0.01%
URML-l	0.07%	0.30%	0.01%	0.06%	0.30%	0.00%	0.17%	0.01%	0.00%	0.01%	0.00%	0.15%	0.04%	0.14%	0.02%	0.06%	0.03%	0.06%	0.00%	0.00%	0.00%		0.07%	0.09%
URMM-l	0.03%	0.18%	0.00%	0.02%	0.18%	0.00%	0.09%	0.00%	0.00%	0.00%	0.00%	0.08%	0.01%	0.07%	0.01%	0.02%	0.01%	0.02%	0.00%	0.00%	0.00%		0.03%	0.06%
Mean	0.01%	0.08%	0.00%	0.01%	0.08%	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.03%	0.01%	0.03%	0.00%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%		0.02%	
Std. Dev.	0.01%	0.07%	0.00%	0.01%	0.07%	0.00%	0.04%	0.00%	0.00%	0.00%	0.00%	0.03%	0.01%	0.03%	0.00%	0.01%	0.01%	0.01%	0.00%	0.00%	0.00%			0.04%

Table 26. Annual frequency of collapse in moderate-seismicity locations

	Annual Frequency of Collapse (λ)																							
Building Type	Portland1	Sacramento1	Spokane1	Boise1	Las Vegas1	Phoenix1	Albequerque1	El Paso1	Denver1	OKC1	Kansas City1	St. Louis1	Urbana1	Nashville 1	Indianapolis1	Louisville 1	Atlanta1	Charlotte 1	Philadelphia1	New York1	Boston1		Mean Value	Standard Deviation
W1-l	3.3E-07	1.6E-07	5.0E-08	4.9E-08	1.9E-07	2.6E-08	2.4E-07	4.5E-07	3.3E-08	8.4E-08	9.5E-09	1.3E-07	4.4E-08	1.5E-07	3.0E-08	5.1E-08	4.7E-08	7.7E-08	8.3E-08	1.0E-07	6.7E-08		1.1E-07	1.1E-07
W2-l	6.3E-07	3.4E-07	9.3E-08	9.7E-08	3.5E-07	4.7E-08	4.4E-07	6.8E-07	5.6E-08	1.5E-07	1.7E-08	2.5E-07	9.1E-08	3.1E-07	6.0E-08	1.0E-07	8.7E-08	1.5E-07	1.4E-07	1.6E-07	1.1E-07		2.1E-07	1.9E-07
S1L-l	6.3E-06	5.3E-06	9.3E-07	1.1E-06	3.7E-06	4.6E-07	3.9E-06	3.7E-06	4.7E-07	1.3E-06	1.8E-07	2.9E-06	1.2E-06	3.6E-06	8.0E-07	1.4E-06	9.7E-07	1.6E-06	1.0E-06	1.1E-06	7.8E-07		2.0E-06	1.7E-06
S1M-l	4.4E-06	4.2E-06	6.6E-07	8.4E-07	2.7E-06	3.3E-07	2.7E-06	2.4E-06	3.3E-07	8.8E-07	1.3E-07	2.1E-06	8.8E-07	2.6E-06	6.0E-07	1.0E-06	7.1E-07	1.2E-06	7.1E-07	7.2E-07	5.2E-07		1.5E-06	1.2E-06
S1H-l	2.9E-06	2.8E-06	4.3E-07	5.5E-07	1.8E-06	2.1E-07	1.7E-06	1.5E-06	2.1E-07	5.7E-07	8.5E-08	1.4E-06	5.8E-07	1.7E-06	4.0E-07	6.7E-07	4.7E-07	7.7E-07	4.6E-07	4.6E-07	3.4E-07		9.5E-07	8.2E-07
S2L-l	5.8E-06	4.9E-06	8.6E-07	1.1E-06	3.5E-06	4.3E-07	3.6E-06	3.5E-06	4.4E-07	1.2E-06	1.6E-07	2.7E-06	1.1E-06	3.3E-06	7.4E-07	1.3E-06	9.0E-07	1.5E-06	9.8E-07	1.0E-06	7.3E-07		1.9E-06	1.6E-06
S2M-l	2.6E-06	2.1E-06	3.8E-07	4.6E-07	1.5E-06	1.9E-07	1.7E-06	1.8E-06	2.0E-07	5.4E-07	7.3E-08	1.2E-06	4.7E-07	1.4E-06	3.2E-07	5.4E-07	3.9E-07	6.6E-07	4.6E-07	4.9E-07	3.5E-07		8.4E-07	7.1E-07
S2H-l	1.4E-06	1.1E-06	2.0E-07	2.4E-07	8.1E-07	1.0E-07	8.7E-07	9.7E-07	1.1E-07	2.9E-07	3.9E-08	6.2E-07	2.5E-07	7.6E-07	1.7E-07	2.8E-07	2.1E-07	3.5E-07	2.4E-07	2.6E-07	1.9E-07		4.5E-07	3.8E-07
S3-l	4.8E-06	5.2E-06	7.3E-07	9.8E-07	3.1E-06	3.6E-07	2.8E-06	2.1E-06	3.5E-07	9.4E-07	1.5E-07	2.4E-06	1.0E-06	2.9E-06	7.2E-07	1.2E-06	8.2E-07	1.3E-06	7.2E-07	7.0E-07	5.2E-07		1.6E-06	1.4E-06
S4L-l	8.1E-06	7.6E-06	1.2E-06	1.5E-06	5.0E-06	6.0E-07	4.9E-06	4.3E-06	6.0E-07	1.6E-06	2.4E-07	3.9E-06	1.6E-06	4.8E-06	1.1E-06	1.9E-06	1.3E-06	2.2E-06	1.3E-06	1.3E-06	9.5E-07		2.7E-06	2.3E-06
S4M-l	3.4E-06	2.8E-06	5.0E-07	6.1E-07	2.0E-06	2.5E-07	2.1E-06	2.1E-06	2.6E-07	6.9E-07	9.6E-08	1.6E-06	6.3E-07	1.9E-06	4.3E-07	7.3E-07	5.2E-07	8.7E-07	5.8E-07	6.0E-07	4.3E-07		1.1E-06	9.3E-07
S4H-l	1.8E-06	1.5E-06	2.6E-07	3.2E-07	1.1E-06	1.3E-07	1.1E-06	1.1E-06	1.4E-07	3.6E-07	5.1E-08	8.2E-07	3.3E-07	1.0E-06	2.3E-07	3.8E-07	2.8E-07	4.6E-07	3.0E-07	3.2E-07	2.3E-07		5.8E-07	4.9E-07
S5L-l	9.4E-06	9.3E-06	1.4E-06	1.8E-06	5.8E-06	7.0E-07	5.7E-06	4.7E-06	6.9E-07	1.9E-06	2.8E-07	4.6E-06	1.9E-06	5.6E-06	1.3E-06	2.2E-06	1.5E-06	2.5E-06	1.5E-06	1.5E-06	1.1E-06		3.1E-06	2.7E-06
S5M-l	4.2E-06	3.9E-06	6.3E-07	7.9E-07	2.6E-06	3.1E-07	2.6E-06	2.3E-06	3.1E-07	8.4E-07	1.2E-07	2.0E-06	8.3E-07	2.4E-06	5.7E-07	9.5E-07	6.7E-07	1.1E-06	6.8E-07	6.9E-07	5.1E-07		1.4E-06	1.2E-06
S5H-l	2.3E-06	2.2E-06	3.5E-07	4.4E-07	1.4E-06	1.7E-07	1.4E-06	1.3E-06	1.7E-07	4.6E-07	6.8E-08	1.1E-06	4.5E-07	1.3E-06	3.1E-07	5.2E-07	3.7E-07	6.1E-07	3.8E-07	3.9E-07	2.8E-07		7.6E-07	6.5E-07
C1L-l	1.6E-05	1.6E-05	2.4E-06	3.1E-06	1.0E-05	1.2E-06	9.6E-06	7.8E-06	1.2E-06	3.2E-06	4.8E-07	7.9E-06	3.3E-06	9.6E-06	2.3E-06	3.8E-06	2.6E-06	4.3E-06	2.5E-06	2.5E-06	1.8E-06		5.3E-06	4.6E-06
C1M-l	8.8E-06	8.6E-06	1.3E-06	1.7E-06	5.5E-06	6.6E-07	5.4E-06	4.8E-06	6.6E-07	1.8E-06	2.6E-07	4.3E-06	1.8E-06	5.2E-06	1.2E-06	2.0E-06	1.4E-06	2.4E-06	1.4E-06	1.4E-06	1.1E-06		2.9E-06	2.5E-06
C1H-l	7.8E-06	9.1E-06	1.2E-06	1.6E-06	5.1E-06	5.9E-07	4.6E-06	3.3E-06	5.7E-07	1.5E-06	2.5E-07	3.9E-06	1.7E-06	4.8E-06	1.2E-06	2.0E-06	1.4E-06	2.2E-06	1.2E-06	1.1E-06	8.5E-07		2.7E-06	2.4E-06
C2L-l	1.1E-05	9.4E-06	1.6E-06	2.0E-06	6.4E-06	7.9E-07	6.6E-06	6.2E-06	8.0E-07	2.2E-06	3.0E-07	5.1E-06	2.1E-06	6.2E-06	1.4E-06	2.4E-06	1.7E-06	2.8E-06	1.8E-06	1.8E-06	1.3E-06		3.5E-06	3.0E-06
C2M-l	5.5E-06	4.5E-06	8.2E-07	9.8E-07	3.3E-06	4.1E-07	3.5E-06	3.7E-06	4.3E-07	1.1E-06	1.6E-07	2.5E-06	1.0E-06	3.1E-06	6.8E-07	1.2E-06	8.5E-07	1.4E-06	9.7E-07	1.0E-06	7.3E-07		1.8E-06	1.5E-06
C2H-l	2.4E-06	1.8E-06	3.6E-07	4.2E-07	1.4E-06	1.8E-07	1.6E-06	1.7E-06	1.9E-07	5.1E-07	6.7E-08	1.1E-06	4.3E-07	1.3E-06	2.9E-07	4.9E-07	3.6E-07	6.1E-07	4.4E-07	4.7E-07	3.3E-07		7.9E-07	6.7E-07
C3L-l	2.2E-05	2.3E-05	3.3E-06	4.4E-06	1.4E-05	1.6E-06	1.3E-05	1.0E-05	1.6E-06	4.3E-06	6.7E-07	1.1E-05	4.7E-06	1.3E-05	3.2E-06	5.4E-06	3.7E-06	6.0E-06	3.4E-06	3.3E-06	2.4E-06		7.3E-06	6.5E-06
C3M-l	1.5E-05	1.6E-05	2.3E-06	3.0E-06	9.5E-06	1.1E-06	9.0E-06	7.2E-06	1.1E-06	3.0E-06	4.6E-07	7.4E-06	3.2E-06	9.0E-06	2.2E-06	3.6E-06	2.5E-06	4.1E-06	2.3E-06	2.3E-06	1.7E-06		5.0E-06	4.4E-06
C3H-l	5.6E-06	6.4E-06	8.8E-07	1.2E-06	3.6E-06	4.3E-07	3.4E-06	2.7E-06	4.2E-07	1.1E-06	1.8E-07	2.8E-06	1.2E-06	3.4E-06	8.5E-07	1.4E-06	9.8E-07	1.6E-06	8.7E-07	8.6E-07	6.4E-07		1.9E-06	1.7E-06
PC1-l	1.6E-05	1.5E-05	2.4E-06	3.1E-06	9.9E-06	1.2E-06	9.9E-06	8.5E-06	1.2E-06	3.2E-06	4.7E-07	7.9E-06	3.3E-06	9.6E-06	2.2E-06	3.7E-06	2.6E-06	4.3E-06	2.6E-06	2.6E-06	1.9E-06		5.3E-06	4.6E-06
PC2L-l	2.1E-05	2.2E-05	3.1E-06	4.1E-06	1.3E-05	1.5E-06	1.2E-05	9.5E-06	1.5E-06	4.0E-06	6.3E-07	1.0E-05	4.4E-06	1.2E-05	3.0E-06	5.0E-06	3.5E-06	5.6E-06	3.1E-06	3.1E-06	2.3E-06		6.9E-06	6.0E-06
PC2M-l	1.2E-05	1.2E-05	1.9E-06	2.4E-06	7.8E-06	9.3E-07	7.6E-06	6.5E-06	9.3E-07	2.5E-06	3.8E-07	6.1E-06	2.6E-06	7.4E-06	1.8E-06	2.9E-06	2.1E-06	3.4E-06	2.0E-06	2.0E-06	1.5E-06		4.2E-06	3.6E-06
PC2H-l	9.3E-06	9.4E-06	1.4E-06	1.8E-06	5.8E-06	6.9E-07	5.6E-06	4.9E-06	6.9E-07	1.9E-06	2.8E-07	4.5E-06	1.9E-06	5.5E-06	1.3E-06	2.2E-06	1.5E-06	2.5E-06	1.5E-06	1.5E-06	1.1E-06		3.1E-06	2.7E-06
RM1L-l	1.0E-05	8.0E-06	1.5E-06	1.8E-06	5.9E-06	7.4E-07	6.3E-06	6.2E-06	7.6E-07	2.0E-06	2.8E-07	4.7E-06	1.8E-06	5.7E-06	1.2E-06	2.1E-06	1.5E-06	2.6E-06	1.7E-06	1.8E-06	1.3E-06		3.2E-06	2.7E-06
RM1M-l	5.3E-06	4.0E-06	7.9E-07	9.2E-07	3.1E-06	3.9E-07	3.4E-06	3.7E-06	4.2E-07	1.1E-06	1.5E-07	2.4E-06	9.4E-07	2.9E-06	6.4E-07	1.1E-06	8.0E-07	1.3E-06	9.5E-07	1.0E-06	7.2E-07		1.7E-06	1.5E-06
RM2L-l	9.8E-06	7.5E-06	1.4E-06	1.7E-06	5.7E-06	7.2E-07	6.2E-06	6.2E-06	7.4E-07	2.0E-06	2.6E-07	4.5E-06	1.8E-06	5.5E-06	1.2E-06	2.0E-06	1.5E-06	2.5E-06	1.7E-06	1.8E-06	1.2E-06		3.1E-06	2.6E-06
RM2M-l	5.3E-06	4.0E-06	7.9E-07	9.2E-07	3.1E-06	3.9E-07	3.4E-06	3.7E-06	4.2E-07	1.1E-06	1.5E-07	2.4E-06	9.4E-07	2.9E-06	6.4E-07	1.1E-06	8.0E-07	1.3E-06	9.5E-07	1.0E-06	7.2E-07		1.7E-06	1.5E-06
RM2H-l	2.8E-06	2.3E-06	4.2E-07	5.1E-07	1.7E-06	2.1E-07	1.8E-06	1.9E-06	2.2E-07	5.8E-07	8.0E-08	1.3E-06	5.2E-07	1.6E-06	3.5E-07	6.0E-07	4.3E-07	7.2E-07	4.9E-07	5.2E-07	3.7E-07		9.2E-07	7.8E-07
URML-l	2.0E-05	2.5E-05	3.2E-06	4.4E-06	1.3E-05	1.5E-06	1.2E-05	8.8E-06	1.5E-06	4.0E-06	6.8E-07	1.0E-05	4.6E-06	1.2E-05	3.2E-06	5.2E-06	3.6E-06	5.7E-06	3.1E-06	2.9E-06	2.2E-06		7.0E-06	6.4E-06
URMM-l	1.8E-05	1.8E-05	2.8E-06	3.6E-06	1.1E-05	1.4E-06	1.1E-05	9.0E-06	1.3E-06	3.6E-06	5.5E-07	9.0E-06	3.8E-06	1.1E-05	2.6E-06	4.4E-06	3.0E-06	5.0E-06	2.9E-06	2.8E-06	2.1E-06		6.1E-06	5.3E-06
Mean	8.1E-06	7.9E-06	1.2E-06	1.6E-06	5.0E-06	6.0E-07	4.9E-06	4.3E-06	6.0E-07	1.6E-06	2.4E-07	3.9E-06	1.6E-06	4.8E-06	1.1E-06	1.9E-06	1.3E-06	2.2E-06	1.3E-06	1.3E-06	9.5E-07		2.7E-06	
Std. Dev.	6.1E-06	6.6E-06	9.3E-07	1.2E-06	3.9E-06	4.5E-07	3.6E-06	2.8E-06	4.4E-07	1.2E-06	1.9E-07	3.0E-06	1.3E-06	3.7E-06	9.1E-07	1.5E-06	1.0E-06	1.7E-06	9.3E-07	9.0E-07	6.7E-07			3.5E-06

Table 27. Score given S_{D1}-level shaking in MCE moderate-seismicity locations

	Score Based on S_{D1}-Level Shaking in MCE Locations (S)																							
Building Type	Portland1	Sacramento1	Spokane1	Boise1	Las Vegas1	Phoenix1	Albequerque1	El Paso1	Denver1	OKC1	Kansas City1	St. Louis1	Urbana1	Nashville 1	Indianapolis1	Louisville 1	Atlanta1	Charlotte 1	Philadelphia1	New York1	Boston1		Mean Value	Standard Deviation
W1-I	6.82	6.48	8.03	7.25	5.87	9.73	6.06	8.49	9.93	8.07	10.40	5.98	7.06	6.05	7.61	6.82	7.53	6.84	9.25	10.02	10.01		7.82	1.52
W2-I	6.43	6.09	7.67	6.87	5.47	9.42	5.66	8.14	9.62	7.71	10.12	5.59	6.68	5.65	7.23	6.43	7.15	6.45	8.92	9.73	9.71		7.46	1.56
S1L-I	4.65	4.36	5.71	5.02	3.84	7.25	4.00	6.12	7.43	5.75	7.88	3.94	4.86	3.99	5.33	4.65	5.27	4.66	6.81	7.52	7.51		5.55	1.35
S1M-I	4.54	4.28	5.48	4.87	3.82	6.85	3.96	5.85	7.01	5.52	7.41	3.91	4.73	3.95	5.15	4.54	5.09	4.55	6.46	7.09	7.08		5.34	1.20
S1H-I	4.69	4.43	5.63	5.02	3.98	6.99	4.12	5.99	7.15	5.66	7.54	4.06	4.88	4.11	5.30	4.69	5.24	4.70	6.60	7.23	7.21		5.49	1.19
S2L-I	4.68	4.39	5.73	5.05	3.88	7.25	4.04	6.13	7.42	5.76	7.86	3.97	4.89	4.03	5.36	4.68	5.29	4.69	6.81	7.51	7.50		5.57	1.34
S2M-I	5.06	4.77	6.07	5.42	4.27	7.53	4.42	6.46	7.70	6.11	8.12	4.36	5.26	4.41	5.71	5.05	5.65	5.07	7.12	7.79	7.77		5.91	1.29
S2H-I	5.28	5.01	6.27	5.63	4.52	7.67	4.67	6.64	7.83	6.30	8.23	4.62	5.48	4.66	5.92	5.28	5.86	5.30	7.27	7.91	7.90		6.11	1.24
S3-I	4.42	4.15	5.41	4.77	3.69	6.88	3.83	5.80	7.06	5.45	7.48	3.77	4.62	3.82	5.06	4.42	5.00	4.44	6.46	7.14	7.13		5.28	1.28
S4L-I	4.36	4.09	5.37	4.72	3.60	6.85	3.75	5.76	7.02	5.41	7.45	3.69	4.56	3.74	5.01	4.36	4.95	4.38	6.42	7.11	7.09		5.22	1.29
S4M-I	4.89	4.60	5.91	5.25	4.10	7.40	4.25	6.31	7.57	5.95	8.00	4.20	5.09	4.24	5.55	4.88	5.48	4.90	6.97	7.66	7.64		5.75	1.31
S4H-I	5.10	4.83	6.07	5.44	4.35	7.47	4.49	6.44	7.64	6.10	8.04	4.43	5.29	4.48	5.73	5.09	5.66	5.11	7.07	7.72	7.70		5.92	1.24
S5L-I	4.23	3.96	5.23	4.59	3.48	6.70	3.63	5.62	6.87	5.27	7.30	3.57	4.43	3.62	4.88	4.23	4.82	4.25	6.28	6.96	6.94		5.09	1.28
S5M-I	4.60	4.34	5.56	4.94	3.87	6.95	4.01	5.93	7.11	5.59	7.51	3.96	4.79	4.00	5.22	4.60	5.16	4.62	6.55	7.19	7.18		5.41	1.22
S5H-I	4.83	4.57	5.77	5.16	4.12	7.11	4.26	6.12	7.27	5.80	7.66	4.20	5.02	4.25	5.43	4.83	5.38	4.85	6.73	7.35	7.33		5.62	1.19
C1L-I	3.97	3.70	4.96	4.32	3.23	6.41	3.37	5.35	6.58	5.00	7.01	3.32	4.17	3.36	4.61	3.97	4.55	3.99	6.00	6.67	6.65		4.82	1.27
C1M-I	4.21	3.95	5.14	4.53	3.50	6.48	3.64	5.49	6.64	5.17	7.03	3.58	4.39	3.63	4.81	4.20	4.75	4.22	6.10	6.72	6.71		4.99	1.18
C1H-I	4.01	3.77	4.88	4.31	3.36	6.16	3.48	5.22	6.31	4.91	6.68	3.43	4.18	3.47	4.57	4.01	4.51	4.02	5.79	6.39	6.37		4.75	1.12
C2L-I	4.34	4.06	5.37	4.70	3.56	6.87	3.71	5.77	7.04	5.41	7.47	3.65	4.54	3.70	5.01	4.34	4.94	4.36	6.44	7.13	7.11		5.22	1.31
C2M-I	4.71	4.43	5.73	5.07	3.93	7.20	4.08	6.12	7.37	5.77	7.79	4.02	4.91	4.07	5.37	4.71	5.31	4.73	6.78	7.46	7.44		5.57	1.29
C2H-I	5.18	4.89	6.24	5.55	4.37	7.75	4.53	6.64	7.93	6.27	8.36	4.47	5.39	4.52	5.86	5.18	5.80	5.20	7.32	8.02	8.00		6.07	1.34
C3L-I	3.81	3.54	4.81	4.16	3.06	6.29	3.20	5.20	6.46	4.84	6.90	3.15	4.00	3.20	4.45	3.81	4.39	3.82	5.86	6.55	6.54		4.67	1.29
C3M-I	3.86	3.61	4.76	4.17	3.17	6.07	3.31	5.10	6.22	4.79	6.60	3.25	4.03	3.30	4.44	3.85	4.38	3.87	5.69	6.30	6.29		4.62	1.15
C3H-I	4.15	3.93	4.99	4.45	3.52	6.19	3.64	5.31	6.33	5.01	6.68	3.60	4.32	3.64	4.69	4.15	4.64	4.17	5.85	6.40	6.39		4.86	1.06
PC1-I	4.12	3.84	5.18	4.49	3.33	6.72	3.48	5.58	6.90	5.21	7.35	3.42	4.33	3.47	4.80	4.12	4.73	4.14	6.28	6.99	6.98		5.02	1.35
PC2L-I	3.80	3.54	4.77	4.14	3.07	6.20	3.21	5.15	6.37	4.81	6.78	3.16	3.99	3.21	4.43	3.80	4.37	3.82	5.79	6.46	6.44		4.63	1.24
PC2M-I	4.01	3.76	4.93	4.34	3.31	6.27	3.45	5.29	6.42	4.96	6.81	3.40	4.20	3.44	4.61	4.01	4.55	4.03	5.88	6.50	6.49		4.79	1.17
PC2H-I	4.11	3.86	5.01	4.43	3.42	6.31	3.56	5.35	6.46	5.04	6.84	3.51	4.29	3.55	4.69	4.11	4.63	4.12	5.94	6.54	6.53		4.87	1.14
RM1L-I	4.65	4.33	5.81	5.06	3.77	7.50	3.94	6.26	7.70	5.85	8.19	3.87	4.88	3.93	5.40	4.65	5.32	4.67	7.02	7.80	7.78		5.64	1.48
RM1M-I	4.88	4.58	5.96	5.26	4.05	7.52	4.21	6.38	7.70	6.00	8.15	4.14	5.09	4.20	5.58	4.88	5.51	4.89	7.08	7.80	7.78		5.79	1.38
RM2L-I	4.75	4.42	5.95	5.17	3.84	7.70	4.02	6.41	7.90	5.99	8.41	3.95	4.99	4.01	5.52	4.75	5.45	4.77	7.20	8.01	7.99		5.77	1.53
RM2M-I	4.88	4.58	5.96	5.26	4.05	7.52	4.21	6.38	7.70	6.00	8.15	4.14	5.09	4.20	5.58	4.88	5.51	4.89	7.08	7.80	7.78		5.79	1.38
RM2H-I	4.94	4.66	5.93	5.29	4.18	7.35	4.32	6.30	7.51	5.96	7.92	4.27	5.13	4.31	5.58	4.93	5.51	4.95	6.94	7.60	7.58		5.77	1.26
URML-I	3.48	3.27	4.27	3.76	2.89	5.41	3.00	4.57	5.55	4.29	5.88	2.96	3.64	2.99	3.99	3.48	3.94	3.49	5.08	5.61	5.60		4.15	1.00
URMM-I	3.95	3.68	4.96	4.31	3.19	6.45	3.34	5.35	6.62	5.00	7.05	3.28	4.15	3.33	4.60	3.95	4.54	3.97	6.02	6.71	6.69		4.82	1.29
Mean	4.58	4.31	5.59	4.94	3.82	7.04	3.97	5.97	7.21	5.62	7.63	3.91	4.78	3.96	5.23	4.58	5.17	4.60	6.62	7.30	7.28		5.43	
Std. Dev.	0.68	0.66	0.75	0.70	0.62	0.85	0.63	0.78	0.86	0.75	0.89	0.63	0.69	0.63	0.73	0.68	0.72	0.68	0.82	0.87	0.87			1.45

Table 28. Score given S_{D1}-level shaking in MCE_R moderate-seismicity locations

Score Based on S_{D1}-Level Shaking in MCE_R Locations (S')																							
Building Type	**Portland1**	**Sacramento1**	**Spokane1**	**Boise1**	**Las Vegas1**	**Phoenix1**	**Albuquerque1**	**El Paso1**	**Denver1**	**OKC1**	**Kansas City1**	**St. Louis1**	**Urbana1**	**Nashville 1**	**Indianapolis1**	**Louisville 1**	**Atlanta1**	**Charlotte 1**	**Philadelphia1**	**New York1**	**Boston1**		**Mean Value**	**Standard Deviation**
W1-I	6.35	5.28	7.37	6.43	5.27	8.91	5.70	7.42	9.26	7.52	9.91	5.78	6.71	5.80	7.16	6.46	6.95	6.45	8.54	9.31	9.33		7.23	1.45
W2-I	5.95	4.88	6.99	6.04	4.87	8.57	5.30	7.04	8.93	7.15	9.61	5.38	6.32	5.40	6.78	6.07	6.56	6.05	8.19	8.98	9.00		6.86	1.48
S1L-I	4.25	3.36	5.13	4.32	3.35	6.50	3.70	5.17	6.82	5.26	7.42	3.77	4.56	3.79	4.94	4.34	4.76	4.33	6.17	6.86	6.88		5.03	1.27
S1M-I	4.18	3.39	4.97	4.24	3.38	6.19	3.69	5.00	6.47	5.09	7.00	3.75	4.46	3.77	4.80	4.27	4.64	4.26	5.89	6.51	6.52		4.88	1.13
S1H-I	4.33	3.55	5.11	4.40	3.55	6.33	3.85	5.15	6.60	5.23	7.13	3.91	4.61	3.93	4.95	4.42	4.79	4.41	6.03	6.65	6.66		5.03	1.12
S2L-I	4.28	3.40	5.15	4.35	3.39	6.51	3.74	5.19	6.82	5.28	7.41	3.81	4.59	3.82	4.97	4.37	4.79	4.36	6.18	6.86	6.88		5.06	1.25
S2M-I	4.66	3.79	5.52	4.73	3.79	6.83	4.13	5.55	7.12	5.64	7.69	4.20	4.96	4.22	5.34	4.76	5.16	4.75	6.51	7.17	7.19		5.42	1.22
S2H-I	4.91	4.06	5.73	4.97	4.06	6.99	4.39	5.77	7.28	5.85	7.82	4.45	5.20	4.47	5.56	4.99	5.39	4.99	6.69	7.32	7.33		5.63	1.17
S3-I	4.05	3.25	4.87	4.12	3.25	6.16	3.56	4.91	6.47	4.99	7.04	3.62	4.34	3.63	4.70	4.14	4.53	4.13	5.85	6.51	6.53		4.79	1.18
S4L-I	3.98	3.14	4.82	4.05	3.14	6.13	3.47	4.86	6.43	4.95	7.00	3.53	4.27	3.55	4.64	4.07	4.47	4.06	5.81	6.47	6.49		4.73	1.21
S4M-I	4.49	3.63	5.35	4.56	3.62	6.68	3.96	5.39	6.98	5.48	7.55	4.03	4.80	4.05	5.17	4.59	5.00	4.58	6.36	7.02	7.04		5.25	1.23
S4H-I	4.72	3.89	5.54	4.79	3.88	6.79	4.21	5.57	7.08	5.66	7.62	4.28	5.01	4.29	5.37	4.81	5.20	4.80	6.49	7.12	7.14		5.44	1.17
S5L-I	3.86	3.04	4.69	3.92	3.03	5.99	3.35	4.72	6.29	4.81	6.86	3.41	4.15	3.43	4.51	3.95	4.34	3.94	5.67	6.33	6.35		4.60	1.19
S5M-I	4.24	3.43	5.04	4.30	3.43	6.28	3.74	5.07	6.56	5.16	7.10	3.80	4.52	3.82	4.87	4.32	4.70	4.31	5.98	6.60	6.62		4.95	1.15
S5H-I	4.47	3.69	5.25	4.54	3.68	6.46	3.99	5.29	6.73	5.37	7.26	4.05	4.75	4.07	5.09	4.56	4.93	4.55	6.17	6.77	6.79		5.16	1.11
C1L-I	3.60	2.79	4.42	3.67	2.78	5.71	3.10	4.46	6.00	4.54	6.57	3.16	3.89	3.18	4.25	3.69	4.08	3.68	5.39	6.05	6.06		4.34	1.18
C1M-I	3.85	3.07	4.63	3.91	3.07	5.83	3.37	4.66	6.10	4.74	6.63	3.43	4.12	3.45	4.46	3.94	4.30	3.93	5.54	6.14	6.16		4.54	1.11
C1H-I	3.68	2.97	4.40	3.74	2.97	5.53	3.24	4.43	5.80	4.51	6.30	3.30	3.93	3.31	4.25	3.76	4.10	3.75	5.26	5.83	5.85		4.33	1.04
C2L-I	3.95	3.09	4.81	4.02	3.08	6.14	3.42	4.85	6.44	4.94	7.03	3.49	4.25	3.50	4.63	4.04	4.45	4.03	5.82	6.49	6.51		4.71	1.23
C2M-I	4.32	3.45	5.17	4.39	3.45	6.49	3.79	5.21	6.79	5.30	7.35	3.85	4.62	3.87	5.00	4.41	4.82	4.40	6.17	6.83	6.85		5.07	1.22
C2H-I	4.78	3.87	5.66	4.85	3.87	7.02	4.22	5.70	7.33	5.79	7.91	4.29	5.09	4.31	5.48	4.87	5.29	4.86	6.69	7.37	7.39		5.55	1.26
C3L-I	3.43	2.62	4.26	3.50	2.62	5.57	2.93	4.30	5.87	4.38	6.45	2.99	3.72	3.01	4.08	3.52	3.91	3.51	5.25	5.92	5.93		4.18	1.20
C3M-I	3.51	2.76	4.26	3.57	2.76	5.43	3.05	4.30	5.70	4.37	6.21	3.11	3.78	3.13	4.10	3.59	3.95	3.59	5.15	5.74	5.75		4.18	1.08
C3H-I	3.84	3.14	4.53	3.89	3.14	5.61	3.41	4.56	5.85	4.63	6.32	3.46	4.08	3.48	4.38	3.91	4.24	3.90	5.35	5.89	5.90		4.45	0.99
PC1-I	3.72	2.86	4.60	3.79	2.85	5.97	3.19	4.64	6.28	4.73	6.89	3.26	4.03	3.27	4.41	3.82	4.23	3.81	5.64	6.33	6.35		4.51	1.26
PC2L-I	3.44	2.64	4.24	3.50	2.64	5.50	2.95	4.28	5.80	4.36	6.36	3.01	3.72	3.02	4.07	3.52	3.90	3.51	5.20	5.84	5.86		4.16	1.16
PC2M-I	3.66	2.89	4.43	3.73	2.89	5.62	3.19	4.46	5.89	4.54	6.41	3.25	3.93	3.27	4.27	3.75	4.11	3.74	5.33	5.93	5.95		4.34	1.10
PC2H-I	3.77	3.01	4.52	3.83	3.01	5.68	3.30	4.55	5.94	4.63	6.45	3.36	4.03	3.38	4.36	3.85	4.21	3.84	5.40	5.98	6.00		4.43	1.07
RM1L-I	4.21	3.24	5.17	4.29	3.24	6.68	3.62	5.22	7.02	5.32	7.68	3.69	4.55	3.71	4.97	4.31	4.77	4.30	6.31	7.07	7.09		5.07	1.39
RM1M-I	4.46	3.54	5.37	4.54	3.54	6.77	3.90	5.41	7.08	5.50	7.69	3.97	4.78	3.99	5.18	4.56	4.99	4.55	6.43	7.13	7.15		5.26	1.30
RM2L-I	4.30	3.30	5.29	4.38	3.30	6.85	3.68	5.34	7.20	5.44	7.89	3.76	4.65	3.78	5.08	4.40	4.88	4.39	6.47	7.26	7.28		5.19	1.43
RM2M-I	4.46	3.54	5.37	4.54	3.54	6.77	3.90	5.41	7.08	5.50	7.69	3.97	4.78	3.99	5.18	4.56	4.99	4.55	6.43	7.13	7.15		5.26	1.30
RM2H-I	4.56	3.71	5.38	4.62	3.71	6.66	4.04	5.42	6.95	5.51	7.50	4.10	4.85	4.12	5.21	4.65	5.04	4.64	6.35	6.99	7.01		5.29	1.18
URML-I	3.18	2.53	3.84	3.24	2.52	4.86	2.78	3.87	5.09	3.94	5.54	2.83	3.41	2.84	3.70	3.25	3.56	3.25	4.61	5.12	5.14		3.77	0.94
URMM-I	3.57	2.74	4.41	3.64	2.74	5.72	3.06	4.45	6.03	4.53	6.61	3.12	3.86	3.14	4.23	3.66	4.06	3.65	5.40	6.07	6.09		4.32	1.21
Mean	4.20	3.36	5.04	4.27	3.35	6.33	3.68	5.07	6.63	5.16	7.20	3.75	4.49	3.76	4.86	4.29	4.69	4.28	6.02	6.67	6.69		4.94	
Std. Dev.	0.65	0.58	0.71	0.66	0.58	0.80	0.61	0.71	0.82	0.72	0.86	0.62	0.67	0.62	0.70	0.66	0.69	0.66	0.78	0.83	0.83			1.36

Table 29. Score based on risk integral in moderate-seismicity locations

	Score Based on Risk Integral (S_R)																						
Building Type	Portland1	Sacramento1	Spokane1	Boise1	Las Vegas1	Phoenix1	Albuquerque1	El Paso1	Denver1	OKC1	Kansas City1	St. Louis1	Urbana1	Nashville1	Indianapolis1	Louisville1	Atlanta1	Charlotte1	Philadelphia1	New York1	Boston1		Mean Value	Standard Deviation
W1-l	4.31	4.62	5.13	5.13	4.55	5.42	4.44	4.17	5.31	4.90	5.85	4.72	5.18	4.64	5.35	5.12	5.15	4.94	4.90	4.82	5.00		4.94	0.40
W2-l	4.03	4.29	4.86	4.84	4.27	5.15	4.18	3.99	5.07	4.66	5.59	4.42	4.87	4.34	5.04	4.80	4.88	4.66	4.69	4.62	4.79		4.67	0.40
S1L-l	3.03	3.10	3.86	3.77	3.25	4.16	3.23	3.25	4.15	3.72	4.58	3.35	3.75	3.27	3.92	3.69	3.84	3.61	3.80	3.79	3.93		3.67	0.39
S1M-l	3.18	3.20	4.00	3.90	3.39	4.31	3.40	3.45	4.31	3.88	4.71	3.50	3.88	3.41	4.04	3.82	3.97	3.76	3.97	3.97	4.10		3.82	0.39
S1H-l	3.37	3.38	4.19	4.08	3.58	4.50	3.58	3.65	4.50	4.07	4.89	3.68	4.06	3.60	4.22	4.00	4.15	3.94	4.16	4.16	4.30		4.00	0.39
S2L-l	3.06	3.14	3.89	3.80	3.28	4.19	3.26	3.27	4.18	3.75	4.61	3.39	3.79	3.30	3.96	3.73	3.87	3.65	3.83	3.82	3.96		3.70	0.39
S2M-l	3.41	3.51	4.24	4.16	3.64	4.54	3.61	3.57	4.52	4.09	4.96	3.75	4.15	3.67	4.32	4.09	4.23	4.01	4.16	4.13	4.28		4.05	0.39
S2H-l	3.69	3.79	4.52	4.44	3.92	4.82	3.88	3.84	4.79	4.37	5.24	4.03	4.43	3.95	4.60	4.37	4.51	4.28	4.43	4.40	4.55		4.33	0.39
S3-l	3.14	3.11	3.96	3.83	3.34	4.27	3.37	3.50	4.28	3.85	4.65	3.44	3.81	3.35	3.97	3.75	3.91	3.70	3.96	3.98	4.10		3.78	0.40
S4L-l	2.92	2.94	3.74	3.64	3.13	4.05	3.13	3.19	4.05	3.62	4.45	3.23	3.61	3.14	3.78	3.55	3.71	3.49	3.71	3.71	3.84		3.55	0.39
S4M-l	3.29	3.37	4.12	4.04	3.52	4.43	3.50	3.50	4.41	3.98	4.84	3.63	4.02	3.54	4.19	3.96	4.11	3.88	4.06	4.04	4.19		3.93	0.39
S4H-l	3.58	3.65	4.40	4.32	3.80	4.71	3.78	3.77	4.69	4.26	5.12	3.91	4.30	3.82	4.47	4.24	4.38	4.16	4.34	4.32	4.46		4.21	0.39
S5L-l	2.85	2.85	3.67	3.56	3.06	3.98	3.07	3.16	3.99	3.55	4.38	3.16	3.54	3.07	3.70	3.48	3.63	3.42	3.65	3.66	3.79		3.49	0.39
S5M-l	3.20	3.23	4.03	3.93	3.42	4.33	3.42	3.46	4.33	3.90	4.74	3.52	3.91	3.44	4.07	3.85	4.00	3.78	3.99	3.98	4.12		3.84	0.39
S5H-l	3.46	3.49	4.28	4.18	3.68	4.59	3.67	3.71	4.59	4.16	4.99	3.78	4.17	3.70	4.33	4.11	4.26	4.04	4.25	4.24	4.38		4.10	0.39
C1L-l	2.62	2.62	3.44	3.33	2.83	3.75	2.84	2.93	3.76	3.32	4.14	2.93	3.30	2.84	3.46	3.24	3.40	3.19	3.43	3.43	3.56		3.26	0.39
C1M-l	2.88	2.89	3.70	3.59	3.09	4.01	3.09	3.15	4.01	3.58	4.40	3.20	3.57	3.11	3.74	3.51	3.67	3.45	3.67	3.67	3.80		3.51	0.39
C1H-l	2.93	2.86	3.74	3.61	3.12	4.05	3.16	3.30	4.07	3.64	4.42	3.23	3.58	3.14	3.74	3.52	3.69	3.48	3.76	3.78	3.90		3.56	0.40
C2L-l	2.80	2.85	3.62	3.53	3.02	3.93	3.00	3.03	3.92	3.49	4.34	3.12	3.51	3.03	3.68	3.45	3.60	3.38	3.58	3.57	3.71		3.44	0.39
C2M-l	3.08	3.17	3.91	3.83	3.31	4.21	3.28	3.25	4.19	3.76	4.63	3.42	3.82	3.33	3.99	3.76	3.90	3.67	3.84	3.81	3.96		3.72	0.39
C2H-l	3.44	3.56	4.27	4.20	3.67	4.57	3.63	3.58	4.54	4.12	5.00	3.78	4.19	3.70	4.36	4.13	4.26	4.04	4.18	4.15	4.30		4.08	0.39
C3L-l	2.48	2.46	3.30	3.18	2.68	3.61	2.71	2.83	3.62	3.19	4.00	2.78	3.15	2.70	3.32	3.09	3.26	3.04	3.30	3.31	3.44		3.12	0.40
C3M-l	2.65	2.62	3.46	3.34	2.85	3.77	2.87	2.96	3.78	3.35	4.16	2.96	3.32	2.87	3.48	3.26	3.42	3.21	3.46	3.46	3.59		3.28	0.39
C3H-l	3.07	3.02	3.88	3.76	3.26	4.19	3.30	3.40	4.20	3.77	4.57	3.38	3.74	3.29	3.89	3.68	3.83	3.63	3.88	3.89	4.02		3.70	0.39
PC1-l	2.61	2.64	3.44	3.33	2.83	3.74	2.83	2.90	3.75	3.31	4.15	2.93	3.31	2.84	3.48	3.25	3.41	3.19	3.41	3.41	3.54		3.25	0.39
PC2L-l	2.51	2.49	3.33	3.21	2.71	3.64	2.74	2.85	3.65	3.22	4.03	2.82	3.18	2.73	3.35	3.12	3.29	3.07	3.33	3.34	3.46		3.15	0.39
PC2M-l	2.73	2.73	3.55	3.44	2.93	3.86	2.95	3.01	3.86	3.43	4.25	3.04	3.42	2.96	3.58	3.36	3.51	3.30	3.52	3.52	3.66		3.36	0.39
PC2H-l	2.86	2.85	3.67	3.56	3.06	3.98	3.07	3.14	3.98	3.55	4.37	3.17	3.54	3.08	3.70	3.48	3.64	3.42	3.65	3.65	3.78		3.49	0.39
RM1L-l	2.82	2.92	3.65	3.57	3.05	3.95	3.02	3.03	3.94	3.51	4.38	3.15	3.56	3.07	3.73	3.50	3.64	3.41	3.59	3.57	3.72		3.47	0.39
RM1M-l	3.10	3.22	3.93	3.86	3.33	4.23	3.29	3.25	4.21	3.78	4.66	3.44	3.85	3.35	4.02	3.79	3.92	3.70	3.85	3.82	3.97		3.74	0.39
RM2L-l	2.83	2.95	3.67	3.59	3.07	3.97	3.03	3.03	3.96	3.53	4.40	3.17	3.58	3.08	3.75	3.52	3.66	3.43	3.60	3.58	3.73		3.48	0.39
RM2M-l	3.10	3.22	3.93	3.86	3.33	4.23	3.29	3.25	4.21	3.78	4.66	3.44	3.85	3.35	4.02	3.79	3.92	3.70	3.85	3.82	3.97		3.74	0.39
RM2H-l	3.38	3.46	4.20	4.12	3.60	4.51	3.57	3.56	4.49	4.06	4.92	3.71	4.11	3.63	4.28	4.05	4.19	3.97	4.14	4.11	4.26		4.01	0.39
URML-l	2.52	2.43	3.32	3.18	2.70	3.64	2.75	2.88	3.65	3.22	3.99	2.82	3.17	2.73	3.32	3.11	3.26	3.06	3.34	3.36	3.48		3.14	0.39
URMM-l	2.56	2.56	3.38	3.27	2.77	3.69	2.78	2.87	3.70	3.26	4.09	2.87	3.24	2.78	3.41	3.18	3.34	3.13	3.37	3.37	3.50		3.20	0.39
Mean	3.07	3.12	3.89	3.80	3.29	4.20	3.28	3.31	4.19	3.76	4.60	3.40	3.78	3.31	3.95	3.72	3.87	3.65	3.85	3.84	3.98		3.71	
Std. Dev.	0.42	0.49	0.42	0.45	0.43	0.42	0.41	0.34	0.40	0.40	0.43	0.44	0.46	0.44	0.46	0.46	0.44	0.44	0.39	0.37	0.38			0.57

Table 30. Performance modification factor given S_{D1}-level shaking in MCE moderate-seismicity locations

Performance Modification Factor Based on S_{D1}-Level Shaking in MCE Locations (PMF)																								
Building Type	**Portland1**	**Sacramento1**	**Spokane1**	**Boise1**	**Las Vegas1**	**Phoenix1**	**Albequerque1**	**El Paso1**	**Denver1**	**OKC1**	**Kansas City1**	**St. Louis1**	**Urbana1**	**Nashville 1**	**Indianapolis1**	**Louisville 1**	**Atlanta1**	**Charlotte 1**	**Philadelphia1**	**New York1**	**Boston1**		**Mean Value**	**Standard Deviation**
W1-l	-2.51	-1.86	-2.90	-2.12	-1.32	-4.31	-1.62	-4.32	-4.62	-3.17	-4.56	-1.27	-1.89	-1.40	-2.26	-1.70	-2.38	-1.90	-4.34	-5.20	-5.01		-2.89	1.35
W2-l	-2.40	-1.80	-2.81	-2.03	-1.20	-4.27	-1.48	-4.14	-4.55	-3.05	-4.53	-1.17	-1.81	-1.31	-2.19	-1.62	-2.27	-1.79	-4.24	-5.11	-4.92		-2.79	1.36
S1L-l	-1.62	-1.26	-1.86	-1.26	-0.59	-3.09	-0.77	-2.87	-3.28	-2.03	-3.30	-0.58	-1.11	-0.72	-1.42	-0.96	-1.43	-1.05	-3.00	-3.73	-3.57		-1.88	1.08
S1M-l	-1.36	-1.08	-1.48	-0.97	-0.43	-2.54	-0.56	-2.40	-2.70	-1.64	-2.70	-0.41	-0.85	-0.54	-1.11	-0.72	-1.12	-0.80	-2.49	-3.13	-2.97		-1.52	0.92
S1H-l	-1.32	-1.06	-1.44	-0.94	-0.40	-2.49	-0.53	-2.34	-2.65	-1.59	-2.65	-0.38	-0.82	-0.51	-1.07	-0.69	-1.08	-0.77	-2.43	-3.07	-2.92		-1.48	0.91
S2L-l	-1.62	-1.26	-1.84	-1.25	-0.60	-3.05	-0.77	-2.86	-3.24	-2.01	-3.25	-0.58	-1.10	-0.72	-1.40	-0.95	-1.42	-1.05	-2.98	-3.70	-3.54		-1.87	1.07
S2M-l	-1.64	-1.26	-1.83	-1.25	-0.63	-2.99	-0.82	-2.89	-3.19	-2.01	-3.16	-0.61	-1.10	-0.75	-1.39	-0.96	-1.42	-1.06	-2.95	-3.66	-3.49		-1.86	1.04
S2H-l	-1.59	-1.22	-1.75	-1.19	-0.61	-2.85	-0.79	-2.80	-3.04	-1.93	-2.99	-0.58	-1.04	-0.72	-1.32	-0.91	-1.35	-1.01	-2.83	-3.51	-3.34		-1.78	0.99
S3-l	-1.28	-1.05	-1.46	-0.94	-0.35	-2.61	-0.46	-2.30	-2.77	-1.60	-2.83	-0.33	-0.81	-0.46	-1.09	-0.67	-1.09	-0.74	-2.49	-3.16	-3.02		-1.50	0.97
S4L-l	-1.45	-1.15	-1.63	-1.08	-0.47	-2.80	-0.62	-2.57	-2.97	-1.79	-3.00	-0.46	-0.95	-0.59	-1.24	-0.81	-1.24	-0.89	-2.71	-3.40	-3.25		-1.67	1.00
S4M-l	-1.59	-1.23	-1.79	-1.21	-0.58	-2.97	-0.76	-2.81	-3.16	-1.96	-3.15	-0.57	-1.07	-0.71	-1.36	-0.92	-1.38	-1.02	-2.91	-3.61	-3.45		-1.82	1.04
S4H-l	-1.52	-1.18	-1.67	-1.12	-0.55	-2.77	-0.71	-2.68	-2.95	-1.84	-2.92	-0.53	-0.98	-0.66	-1.26	-0.85	-1.28	-0.95	-2.73	-3.40	-3.24		-1.70	0.98
S5L-l	-1.39	-1.11	-1.56	-1.03	-0.43	-2.72	-0.56	-2.47	-2.89	-1.72	-2.92	-0.41	-0.90	-0.55	-1.18	-0.76	-1.18	-0.83	-2.62	-3.30	-3.15		-1.60	0.99
S5M-l	-1.40	-1.11	-1.54	-1.02	-0.46	-2.62	-0.60	-2.47	-2.78	-1.69	-2.78	-0.43	-0.88	-0.57	-1.15	-0.75	-1.16	-0.84	-2.56	-3.21	-3.06		-1.57	0.94
S5H-l	-1.37	-1.08	-1.48	-0.98	-0.44	-2.52	-0.58	-2.42	-2.68	-1.64	-2.66	-0.42	-0.85	-0.55	-1.10	-0.72	-1.12	-0.80	-2.48	-3.11	-2.96		-1.52	0.91
C1L-l	-1.35	-1.09	-1.52	-0.99	-0.41	-2.66	-0.53	-2.41	-2.83	-1.67	-2.86	-0.39	-0.87	-0.52	-1.15	-0.73	-1.15	-0.80	-2.57	-3.24	-3.09		-1.56	0.97
C1M-l	-1.33	-1.06	-1.44	-0.94	-0.41	-2.48	-0.54	-2.35	-2.63	-1.59	-2.62	-0.39	-0.82	-0.52	-1.07	-0.69	-1.08	-0.77	-2.43	-3.06	-2.90		-1.48	0.90
C1H-l	-1.08	-0.91	-1.14	-0.71	-0.24	-2.10	-0.32	-1.91	-2.24	-1.27	-2.26	-0.21	-0.60	-0.33	-0.83	-0.48	-0.83	-0.54	-2.03	-2.61	-2.47		-1.20	0.81
C2L-l	-1.55	-1.21	-1.75	-1.18	-0.54	-2.94	-0.71	-2.73	-3.12	-1.91	-3.13	-0.53	-1.03	-0.67	-1.33	-0.89	-1.34	-0.98	-2.86	-3.56	-3.41		-1.78	1.04
C2M-l	-1.63	-1.26	-1.82	-1.24	-0.62	-2.99	-0.80	-2.87	-3.18	-2.00	-3.16	-0.60	-1.09	-0.74	-1.38	-0.95	-1.41	-1.05	-2.94	-3.65	-3.48		-1.85	1.04
C2H-l	-1.74	-1.33	-1.97	-1.35	-0.70	-3.18	-0.90	-3.06	-3.38	-2.15	-3.36	-0.68	-1.20	-0.82	-1.50	-1.05	-1.53	-1.16	-3.13	-3.87	-3.70		-1.99	1.09
C3L-l	-1.33	-1.07	-1.51	-0.98	-0.38	-2.68	-0.50	-2.37	-2.84	-1.65	-2.90	-0.36	-0.85	-0.50	-1.14	-0.71	-1.13	-0.78	-2.56	-3.24	-3.10		-1.55	0.99
C3M-l	-1.21	-0.99	-1.29	-0.83	-0.33	-2.29	-0.43	-2.14	-2.44	-1.43	-2.44	-0.30	-0.71	-0.43	-0.95	-0.59	-0.96	-0.66	-2.23	-2.84	-2.69		-1.34	0.86
C3H-l	-1.08	-0.91	-1.10	-0.69	-0.26	-2.00	-0.35	-1.91	-2.13	-1.24	-2.11	-0.22	-0.58	-0.34	-0.80	-0.48	-0.81	-0.54	-1.96	-2.51	-2.37		-1.16	0.77
PC1-l	-1.51	-1.19	-1.74	-1.16	-0.50	-2.98	-0.66	-2.69	-3.16	-1.90	-3.20	-0.50	-1.02	-0.63	-1.32	-0.87	-1.33	-0.95	-2.87	-3.59	-3.43		-1.77	1.06
PC2L-l	-1.29	-1.05	-1.44	-0.93	-0.36	-2.56	-0.48	-2.30	-2.72	-1.59	-2.76	-0.34	-0.81	-0.48	-1.08	-0.68	-1.08	-0.74	-2.46	-3.12	-2.97		-1.49	0.95
PC2M-l	-1.29	-1.03	-1.39	-0.90	-0.38	-2.41	-0.51	-2.28	-2.57	-1.54	-2.56	-0.36	-0.78	-0.49	-1.03	-0.66	-1.04	-0.73	-2.36	-2.98	-2.83		-1.43	0.89
PC2H-l	-1.25	-1.01	-1.34	-0.87	-0.37	-2.33	-0.48	-2.22	-2.48	-1.48	-2.47	-0.34	-0.75	-0.47	-0.99	-0.63	-1.00	-0.70	-2.29	-2.89	-2.74		-1.38	0.86
RM1L-l	-1.83	-1.41	-2.16	-1.48	-0.72	-3.55	-0.92	-3.23	-3.76	-2.34	-3.80	-0.72	-1.32	-0.86	-1.67	-1.15	-1.68	-1.25	-3.42	-4.23	-4.06		-2.17	1.21
RM1M-l	-1.78	-1.36	-2.03	-1.40	-0.72	-3.29	-0.92	-3.13	-3.50	-2.22	-3.50	-0.70	-1.24	-0.84	-1.56	-1.09	-1.59	-1.20	-3.23	-3.98	-3.81		-2.05	1.12
RM2L-l	-1.92	-1.47	-2.28	-1.58	-0.78	-3.73	-0.99	-3.38	-3.95	-2.47	-4.01	-0.78	-1.41	-0.93	-1.77	-1.23	-1.79	-1.34	-3.59	-4.43	-4.26		-2.29	1.26
RM2M-l	-1.78	-1.36	-2.03	-1.40	-0.72	-3.29	-0.92	-3.13	-3.50	-2.22	-3.50	-0.70	-1.24	-0.84	-1.56	-1.09	-1.59	-1.20	-3.23	-3.98	-3.81		-2.05	1.12
RM2H-l	-1.56	-1.21	-1.72	-1.17	-0.58	-2.84	-0.75	-2.75	-3.02	-1.90	-3.00	-0.55	-1.02	-0.69	-1.30	-0.89	-1.33	-0.98	-2.81	-3.48	-3.32		-1.76	1.00
URML-l	-0.96	-0.83	-0.95	-0.57	-0.19	-1.78	-0.25	-1.69	-1.90	-1.07	-1.88	-0.14	-0.47	-0.26	-0.67	-0.37	-0.68	-0.43	-1.74	-2.26	-2.12		-1.01	0.71
URMM-l	-1.39	-1.11	-1.58	-1.04	-0.43	-2.76	-0.56	-2.48	-2.92	-1.73	-2.96	-0.42	-0.91	-0.55	-1.20	-0.77	-1.20	-0.84	-2.65	-3.34	-3.19		-1.62	1.00
Mean	-1.51	-1.19	-1.69	-1.14	-0.53	-2.84	-0.69	-2.67	-3.02	-1.86	-3.02	-0.51	-1.00	-0.65	-1.28	-0.86	-1.30	-0.95	-2.78	-3.46	-3.30		-1.73	
Std. Dev.	0.32	0.22	0.41	0.32	0.23	0.54	0.28	0.55	0.58	0.44	0.58	0.23	0.30	0.24	0.33	0.28	0.35	0.31	0.55	0.62	0.61			1.06

Table 31. Performance modification factor given S_{D1}-level shaking in MCE_R moderate-seismicity locations

Performance Modification Factor Based on S_{D1}-Level Shaking in MCE_R Locations (PMF')																								
Building Type	**Portland1**	**Sacramento1**	**Spokane1**	**Boise1**	**Las Vegas1**	**Phoenix1**	**Albequerque1**	**El Paso1**	**Denver1**	**OKC1**	**Kansas City1**	**St. Louis1**	**Urbana1**	**Nashville1**	**Indianapolis1**	**Louisville1**	**Atlanta1**	**Charlotte1**	**Philadelphia1**	**New York1**	**Boston1**		**Mean Value**	**Standard Deviation**
W1-I	-2.04	-0.66	-2.25	-1.30	-0.72	-3.49	-1.26	-3.25	-3.95	-2.62	-4.06	-1.06	-1.54	-1.16	-1.81	-1.35	-1.80	-1.51	-3.64	-4.49	-4.33		-2.30	1.26
W2-I	-1.93	-0.59	-2.14	-1.20	-0.60	-3.43	-1.12	-3.05	-3.86	-2.49	-4.01	-0.96	-1.46	-1.06	-1.73	-1.26	-1.68	-1.40	-3.51	-4.37	-4.21		-2.19	1.26
S1L-I	-1.22	-0.26	-1.27	-0.55	-0.10	-2.34	-0.47	-1.92	-2.67	-1.54	-2.84	-0.41	-0.81	-0.52	-1.03	-0.65	-0.92	-0.72	-2.37	-3.07	-2.95		-1.36	0.98
S1M-I	-1.00	-0.19	-0.96	-0.34	0.01	-1.88	-0.30	-1.56	-2.16	-1.21	-2.29	-0.25	-0.58	-0.36	-0.76	-0.44	-0.67	-0.50	-1.92	-2.54	-2.42		-1.06	0.83
S1H-I	-0.97	-0.18	-0.93	-0.32	0.03	-1.83	-0.27	-1.50	-2.11	-1.16	-2.24	-0.23	-0.55	-0.33	-0.73	-0.42	-0.64	-0.47	-1.87	-2.48	-2.36		-1.03	0.82
S2L-I	-1.22	-0.26	-1.26	-0.55	-0.11	-2.32	-0.47	-1.92	-2.64	-1.53	-2.80	-0.42	-0.80	-0.52	-1.01	-0.65	-0.92	-0.71	-2.35	-3.05	-2.92		-1.35	0.96
S2M-I	-1.25	-0.28	-1.28	-0.57	-0.15	-2.29	-0.52	-1.98	-2.61	-1.55	-2.73	-0.45	-0.81	-0.55	-1.02	-0.66	-0.93	-0.74	-2.35	-3.03	-2.90		-1.36	0.94
S2H-I	-1.22	-0.27	-1.21	-0.53	-0.14	-2.17	-0.51	-1.93	-2.48	-1.49	-2.58	-0.42	-0.76	-0.52	-0.96	-0.62	-0.88	-0.70	-2.25	-2.91	-2.78		-1.30	0.90
S3-I	-0.91	-0.14	-0.91	-0.28	0.09	-1.89	-0.19	-1.40	-2.18	-1.14	-2.39	-0.18	-0.53	-0.28	-0.73	-0.39	-0.62	-0.43	-1.89	-2.53	-2.42		-1.02	0.86
S4L-I	-1.07	-0.20	-1.08	-0.41	-0.01	-2.08	-0.34	-1.66	-2.38	-1.33	-2.55	-0.30	-0.66	-0.40	-0.86	-0.52	-0.76	-0.57	-2.10	-2.77	-2.65		-1.18	0.90
S4M-I	-1.20	-0.26	-1.23	-0.53	-0.11	-2.25	-0.47	-1.89	-2.57	-1.50	-2.71	-0.40	-0.77	-0.51	-0.98	-0.63	-0.89	-0.69	-2.29	-2.98	-2.85		-1.32	0.94
S4H-I	-1.14	-0.24	-1.14	-0.47	-0.09	-2.09	-0.43	-1.81	-2.39	-1.40	-2.50	-0.37	-0.71	-0.47	-0.90	-0.57	-0.81	-0.64	-2.15	-2.80	-2.67		-1.23	0.88
S5L-I	-1.01	-0.18	-1.02	-0.36	0.03	-2.01	-0.28	-1.57	-2.30	-1.26	-2.48	-0.25	-0.61	-0.36	-0.81	-0.47	-0.71	-0.52	-2.02	-2.67	-2.56		-1.11	0.88
S5M-I	-1.03	-0.20	-1.01	-0.38	-0.01	-1.94	-0.33	-1.62	-2.23	-1.26	-2.36	-0.28	-0.61	-0.38	-0.80	-0.48	-0.71	-0.53	-1.99	-2.62	-2.50		-1.11	0.85
S5H-I	-1.01	-0.19	-0.97	-0.35	-0.01	-1.87	-0.32	-1.58	-2.15	-1.21	-2.26	-0.27	-0.58	-0.37	-0.76	-0.45	-0.67	-0.51	-1.92	-2.54	-2.41		-1.07	0.82
C1L-I	-0.98	-0.17	-0.98	-0.34	0.04	-1.96	-0.26	-1.52	-2.25	-1.22	-2.43	-0.23	-0.59	-0.34	-0.78	-0.45	-0.68	-0.49	-1.97	-2.61	-2.50		-1.08	0.87
C1M-I	-0.97	-0.18	-0.93	-0.32	0.02	-1.82	-0.28	-1.52	-2.10	-1.17	-2.22	-0.24	-0.55	-0.34	-0.73	-0.42	-0.64	-0.48	-1.87	-2.48	-2.36		-1.03	0.81
C1H-I	-0.75	-0.11	-0.66	-0.13	0.15	-1.48	-0.08	-1.13	-1.73	-0.87	-1.87	-0.07	-0.35	-0.17	-0.51	-0.23	-0.42	-0.27	-1.50	-2.06	-1.95		-0.77	0.72
C2L-I	-1.15	-0.24	-1.18	-0.49	-0.07	-2.21	-0.42	-1.81	-2.52	-1.44	-2.69	-0.37	-0.74	-0.47	-0.95	-0.59	-0.85	-0.65	-2.24	-2.92	-2.80		-1.28	0.94
C2M-I	-1.24	-0.28	-1.26	-0.56	-0.14	-2.28	-0.51	-1.96	-2.60	-1.54	-2.72	-0.44	-0.80	-0.54	-1.01	-0.65	-0.92	-0.73	-2.33	-3.02	-2.89		-1.35	0.94
C2H-I	-1.34	-0.32	-1.39	-0.65	-0.20	-2.45	-0.59	-2.12	-2.78	-1.67	-2.92	-0.51	-0.89	-0.61	-1.11	-0.74	-1.03	-0.82	-2.51	-3.22	-3.09		-1.47	0.99
C3L-I	-0.95	-0.16	-0.96	-0.32	0.07	-1.96	-0.22	-1.47	-2.25	-1.19	-2.45	-0.21	-0.57	-0.31	-0.77	-0.43	-0.66	-0.47	-1.95	-2.60	-2.49		-1.06	0.88
C3M-I	-0.86	-0.14	-0.80	-0.23	0.09	-1.65	-0.18	-1.33	-1.92	-1.02	-2.05	-0.16	-0.45	-0.26	-0.62	-0.33	-0.53	-0.38	-1.69	-2.27	-2.16		-0.90	0.77
C3H-I	-0.76	-0.12	-0.65	-0.14	0.12	-1.41	-0.11	-1.16	-1.65	-0.86	-1.76	-0.09	-0.34	-0.18	-0.49	-0.24	-0.41	-0.28	-1.46	-2.00	-1.88		-0.76	0.68
PC1-I	-1.11	-0.22	-1.16	-0.46	-0.03	-2.22	-0.36	-1.74	-2.54	-1.42	-2.74	-0.33	-0.72	-0.44	-0.94	-0.57	-0.83	-0.62	-2.23	-2.92	-2.80		-1.26	0.95
PC2L-I	-0.92	-0.15	-0.91	-0.29	0.07	-1.86	-0.21	-1.43	-2.15	-1.14	-2.33	-0.19	-0.53	-0.29	-0.72	-0.40	-0.62	-0.44	-1.87	-2.50	-2.39		-1.01	0.84
PC2M-I	-0.94	-0.17	-0.88	-0.29	0.04	-1.76	-0.25	-1.45	-2.03	-1.12	-2.16	-0.21	-0.52	-0.31	-0.69	-0.39	-0.60	-0.44	-1.81	-2.41	-2.29		-0.98	0.80
PC2H-I	-0.91	-0.16	-0.84	-0.27	0.05	-1.70	-0.23	-1.41	-1.96	-1.07	-2.08	-0.19	-0.49	-0.29	-0.66	-0.37	-0.57	-0.42	-1.75	-2.33	-2.21		-0.95	0.77
RM1L-I	-1.39	-0.32	-1.52	-0.71	-0.19	-2.72	-0.59	-2.19	-3.08	-1.81	-3.30	-0.54	-0.99	-0.64	-1.24	-0.82	-1.13	-0.89	-2.72	-3.50	-3.38		-1.60	1.10
RM1M-I	-1.37	-0.32	-1.44	-0.68	-0.21	-2.54	-0.61	-2.16	-2.88	-1.73	-3.03	-0.53	-0.93	-0.63	-1.16	-0.77	-1.07	-0.85	-2.58	-3.32	-3.18		-1.52	1.02
RM2L-I	-1.46	-0.35	-1.62	-0.78	-0.23	-2.88	-0.65	-2.30	-3.25	-1.92	-3.48	-0.59	-1.07	-0.70	-1.33	-0.89	-1.22	-0.96	-2.87	-3.68	-3.55		-1.70	1.15
RM2M-I	-1.37	-0.32	-1.44	-0.68	-0.21	-2.54	-0.61	-2.16	-2.88	-1.73	-3.03	-0.53	-0.93	-0.63	-1.16	-0.77	-1.07	-0.85	-2.58	-3.32	-3.18		-1.52	1.02
RM2H-I	-1.18	-0.26	-1.18	-0.50	-0.11	-2.15	-0.46	-1.87	-2.46	-1.45	-2.58	-0.39	-0.74	-0.50	-0.94	-0.60	-0.85	-0.67	-2.22	-2.88	-2.75		-1.27	0.90
URML-I	-0.66	-0.10	-0.52	-0.05	0.17	-1.22	-0.03	-0.99	-1.44	-0.71	-1.54	-0.01	-0.25	-0.11	-0.38	-0.15	-0.30	-0.18	-1.27	-1.77	-1.66		-0.63	0.62
URMM-I	-1.01	-0.18	-1.03	-0.37	0.03	-2.03	-0.28	-1.57	-2.33	-1.27	-2.52	-0.26	-0.62	-0.36	-0.82	-0.48	-0.72	-0.52	-2.04	-2.70	-2.59		-1.13	0.90
Mean	-1.13	-0.24	-1.14	-0.47	-0.07	-2.13	-0.41	-1.77	-2.44	-1.40	-2.59	-0.35	-0.71	-0.45	-0.91	-0.57	-0.82	-0.63	-2.17	-2.84	-2.72		-1.24	
Std. Dev.	0.29	0.12	0.36	0.26	0.18	0.48	0.25	0.47	0.53	0.40	0.54	0.22	0.27	0.22	0.30	0.25	0.31	0.28	0.49	0.57	0.56			0.96

Table 32. Discrepancy factor given S_{M1}-level shaking for MCE moderate-seismicity locations

Discrepancy Factor Based on S_{M1}-Level Shaking in MCE Locations (D)																								
Building Type	Portland1	Sacramento1	Spokane1	Boise1	Las Vegas1	Phoenix1	Albuquerque1	El Paso1	Denver1	OKC1	Kansas City1	St. Louis1	Urbana1	Nashville 1	Indianapolis1	Louisville 1	Atlanta1	Charlotte 1	Philadelphia1	New York1	Boston1		Mean Value	Standard Deviation
W1-l	0.28	0.31	0.21	0.25	0.36	0.14	0.34	0.18	0.13	0.20	0.12	0.35	0.26	0.35	0.23	0.28	0.23	0.28	0.16	0.13	0.13		0.23	0.08
W2-l	0.34	0.37	0.25	0.30	0.44	0.17	0.42	0.22	0.16	0.25	0.15	0.43	0.32	0.42	0.28	0.34	0.28	0.34	0.19	0.16	0.16		0.29	0.10
S1L-l	0.51	0.56	0.37	0.45	0.66	0.26	0.63	0.34	0.25	0.37	0.22	0.64	0.48	0.63	0.42	0.51	0.42	0.51	0.28	0.24	0.24		0.43	0.15
S1M-l	0.53	0.58	0.39	0.47	0.69	0.27	0.65	0.35	0.25	0.38	0.23	0.67	0.49	0.65	0.43	0.53	0.44	0.52	0.29	0.25	0.25		0.44	0.15
S1H-l	0.54	0.59	0.40	0.48	0.71	0.27	0.67	0.36	0.26	0.40	0.24	0.68	0.51	0.67	0.44	0.54	0.45	0.54	0.30	0.26	0.26		0.46	0.16
S2L-l	0.50	0.54	0.36	0.44	0.65	0.25	0.61	0.33	0.24	0.36	0.22	0.63	0.46	0.62	0.40	0.50	0.41	0.49	0.28	0.23	0.24		0.42	0.14
S2M-l	0.44	0.49	0.33	0.40	0.58	0.22	0.55	0.29	0.21	0.32	0.19	0.56	0.41	0.55	0.36	0.44	0.37	0.44	0.25	0.21	0.21		0.37	0.13
S2H-l	0.42	0.46	0.31	0.38	0.55	0.21	0.52	0.28	0.20	0.31	0.19	0.53	0.40	0.52	0.35	0.42	0.35	0.42	0.24	0.20	0.20		0.36	0.12
S3-l	0.65	0.71	0.48	0.58	0.85	0.33	0.80	0.43	0.31	0.47	0.28	0.82	0.61	0.81	0.53	0.65	0.54	0.65	0.36	0.31	0.31		0.55	0.19
S4L-l	0.55	0.61	0.41	0.49	0.72	0.28	0.69	0.37	0.27	0.40	0.24	0.70	0.52	0.69	0.45	0.55	0.46	0.55	0.31	0.26	0.26		0.47	0.16
S4M-l	0.48	0.53	0.36	0.43	0.63	0.24	0.60	0.32	0.23	0.35	0.21	0.61	0.45	0.60	0.40	0.48	0.40	0.48	0.27	0.23	0.23		0.41	0.14
S4H-l	0.46	0.51	0.34	0.41	0.60	0.23	0.57	0.30	0.22	0.34	0.20	0.58	0.43	0.57	0.38	0.46	0.38	0.46	0.26	0.22	0.22		0.39	0.13
S5L-l	0.58	0.64	0.43	0.52	0.76	0.29	0.72	0.39	0.28	0.43	0.26	0.74	0.55	0.72	0.48	0.58	0.49	0.58	0.33	0.28	0.28		0.49	0.17
S5M-l	0.52	0.57	0.38	0.46	0.68	0.26	0.64	0.34	0.25	0.38	0.23	0.65	0.49	0.64	0.42	0.52	0.43	0.52	0.29	0.25	0.25		0.44	0.15
S5H-l	0.50	0.55	0.37	0.45	0.66	0.25	0.62	0.33	0.24	0.37	0.22	0.63	0.47	0.62	0.41	0.50	0.42	0.50	0.28	0.24	0.24		0.42	0.15
C1L-l	0.59	0.65	0.44	0.53	0.77	0.30	0.73	0.39	0.29	0.43	0.26	0.75	0.56	0.74	0.48	0.59	0.49	0.59	0.33	0.28	0.28		0.50	0.17
C1M-l	0.53	0.58	0.39	0.47	0.69	0.27	0.65	0.35	0.25	0.38	0.23	0.67	0.49	0.66	0.43	0.53	0.44	0.52	0.29	0.25	0.25		0.44	0.15
C1H-l	0.65	0.71	0.48	0.58	0.84	0.33	0.80	0.43	0.31	0.47	0.28	0.82	0.61	0.80	0.53	0.65	0.54	0.64	0.36	0.31	0.31		0.54	0.19
C2L-l	0.52	0.57	0.38	0.46	0.67	0.26	0.64	0.34	0.25	0.38	0.23	0.65	0.48	0.64	0.42	0.52	0.43	0.51	0.29	0.24	0.25		0.43	0.15
C2M-l	0.45	0.50	0.33	0.40	0.59	0.23	0.56	0.30	0.22	0.33	0.20	0.57	0.42	0.56	0.37	0.45	0.38	0.45	0.25	0.21	0.22		0.38	0.13
C2H-l	0.43	0.48	0.32	0.39	0.57	0.22	0.54	0.29	0.21	0.32	0.19	0.55	0.41	0.54	0.35	0.43	0.36	0.43	0.24	0.21	0.21		0.37	0.13
C3L-l	0.63	0.69	0.46	0.56	0.82	0.32	0.78	0.42	0.30	0.46	0.28	0.79	0.59	0.78	0.51	0.63	0.52	0.63	0.35	0.30	0.30		0.53	0.18
C3M-l	0.58	0.64	0.43	0.52	0.76	0.29	0.72	0.38	0.28	0.42	0.25	0.73	0.54	0.72	0.47	0.58	0.48	0.58	0.32	0.27	0.28		0.49	0.17
C3H-l	0.57	0.63	0.42	0.51	0.75	0.29	0.71	0.38	0.28	0.42	0.25	0.73	0.54	0.71	0.47	0.57	0.48	0.57	0.32	0.27	0.27		0.48	0.17
PC1-l	0.57	0.62	0.42	0.51	0.74	0.29	0.70	0.38	0.27	0.41	0.25	0.72	0.53	0.70	0.46	0.57	0.47	0.56	0.32	0.27	0.27		0.48	0.16
PC2L-l	0.61	0.67	0.45	0.55	0.80	0.31	0.76	0.41	0.30	0.45	0.27	0.78	0.58	0.76	0.50	0.62	0.51	0.61	0.34	0.29	0.29		0.52	0.18
PC2M-l	0.54	0.60	0.40	0.49	0.71	0.27	0.67	0.36	0.26	0.40	0.24	0.69	0.51	0.67	0.44	0.54	0.45	0.54	0.30	0.26	0.26		0.46	0.16
PC2H-l	0.54	0.59	0.40	0.48	0.70	0.27	0.66	0.36	0.26	0.39	0.24	0.68	0.50	0.67	0.44	0.54	0.45	0.53	0.30	0.25	0.26		0.45	0.16
RM1L-l	0.51	0.56	0.37	0.45	0.66	0.26	0.63	0.34	0.25	0.37	0.22	0.64	0.48	0.63	0.41	0.51	0.42	0.50	0.28	0.24	0.24		0.43	0.15
RM1M-l	0.45	0.49	0.33	0.40	0.59	0.23	0.55	0.30	0.22	0.33	0.20	0.57	0.42	0.56	0.37	0.45	0.37	0.45	0.25	0.21	0.21		0.38	0.13
RM2L-l	0.50	0.55	0.37	0.45	0.66	0.25	0.62	0.33	0.24	0.37	0.22	0.63	0.47	0.62	0.41	0.50	0.42	0.50	0.28	0.24	0.24		0.42	0.15
RM2M-l	0.45	0.49	0.33	0.40	0.59	0.23	0.55	0.30	0.22	0.33	0.20	0.57	0.42	0.56	0.37	0.45	0.37	0.45	0.25	0.21	0.21		0.38	0.13
RM2H-l	0.45	0.50	0.33	0.41	0.59	0.23	0.56	0.30	0.22	0.33	0.20	0.57	0.43	0.56	0.37	0.45	0.38	0.45	0.25	0.21	0.22		0.38	0.13
URML-l	0.61	0.67	0.45	0.55	0.80	0.31	0.76	0.41	0.30	0.45	0.27	0.77	0.57	0.76	0.50	0.61	0.51	0.61	0.34	0.29	0.29		0.52	0.18
URMM-l	0.59	0.65	0.44	0.53	0.77	0.30	0.73	0.39	0.29	0.43	0.26	0.75	0.55	0.73	0.48	0.59	0.49	0.59	0.33	0.28	0.28		0.50	0.17
Mean	0.52	0.57	0.38	0.46	0.68	0.26	0.64	0.34	0.25	0.38	0.23	0.65	0.48	0.64	0.42	0.52	0.43	0.51	0.29	0.24	0.25		0.44	
Std. Dev.	0.08	0.09	0.06	0.07	0.11	0.04	0.10	0.05	0.04	0.06	0.04	0.10	0.08	0.10	0.07	0.08	0.07	0.08	0.05	0.04	0.04			0.16

Table 33. Discrepancy factor given S_{M1}-level shaking for MCE_R moderate-seismicity locations

Discrepancy Factor Based on S_{M1}-Level Shaking in MCE_R Locations (D')																							
Building Type	Portland1	Sacramento1	Spokane1	Boise1	Las Vegas1	Phoenix1	Albequerque1	El Paso1	Denver1	OKC1	Kansas City1	St. Louis1	Urbana1	Nashville 1	Indianapolis1	Louisville 1	Atlanta1	Charlotte 1	Philadelphia1	New York1	Boston1		Mean Value	Standard Deviation
W1-I	0.32	0.44	0.24	0.31	0.44	0.17	0.38	0.24	0.16	0.23	0.14	0.37	0.29	0.37	0.25	0.31	0.27	0.31	0.18	0.15	0.15		0.27	0.09
W2-I	0.39	0.53	0.29	0.38	0.53	0.20	0.47	0.29	0.19	0.28	0.16	0.45	0.35	0.45	0.31	0.37	0.33	0.37	0.22	0.19	0.19		0.33	0.11
S1L-I	0.58	0.80	0.44	0.56	0.80	0.31	0.70	0.44	0.28	0.42	0.25	0.68	0.52	0.68	0.46	0.56	0.49	0.56	0.33	0.28	0.28		0.50	0.17
S1M-I	0.60	0.83	0.46	0.59	0.83	0.32	0.73	0.45	0.29	0.44	0.26	0.71	0.54	0.70	0.48	0.58	0.51	0.58	0.34	0.29	0.29		0.51	0.18
S1H-I	0.62	0.85	0.47	0.60	0.85	0.33	0.75	0.46	0.30	0.45	0.26	0.73	0.56	0.72	0.50	0.60	0.52	0.60	0.35	0.30	0.30		0.53	0.18
S2L-I	0.56	0.78	0.43	0.55	0.78	0.30	0.68	0.42	0.28	0.41	0.24	0.67	0.51	0.66	0.45	0.55	0.48	0.55	0.32	0.27	0.27		0.48	0.17
S2M-I	0.50	0.70	0.38	0.49	0.70	0.27	0.61	0.38	0.25	0.37	0.21	0.59	0.46	0.59	0.40	0.49	0.43	0.49	0.29	0.24	0.24		0.43	0.15
S2H-I	0.48	0.66	0.37	0.47	0.67	0.25	0.58	0.36	0.24	0.35	0.20	0.57	0.43	0.56	0.39	0.47	0.41	0.47	0.28	0.23	0.23		0.41	0.14
S3-I	0.74	1.02	0.56	0.72	1.02	0.39	0.89	0.56	0.36	0.54	0.31	0.87	0.67	0.87	0.59	0.72	0.63	0.72	0.42	0.36	0.36		0.63	0.22
S4L-I	0.63	0.87	0.48	0.62	0.87	0.33	0.76	0.47	0.31	0.46	0.27	0.74	0.57	0.74	0.51	0.61	0.53	0.61	0.36	0.31	0.30		0.54	0.19
S4M-I	0.55	0.76	0.42	0.54	0.76	0.29	0.67	0.41	0.27	0.40	0.23	0.65	0.50	0.65	0.44	0.53	0.47	0.54	0.32	0.27	0.27		0.47	0.16
S4H-I	0.52	0.72	0.40	0.51	0.73	0.28	0.63	0.39	0.26	0.38	0.22	0.62	0.47	0.61	0.42	0.51	0.44	0.51	0.30	0.25	0.25		0.45	0.16
S5L-I	0.66	0.92	0.51	0.65	0.92	0.35	0.80	0.50	0.33	0.49	0.28	0.78	0.60	0.78	0.53	0.64	0.56	0.65	0.38	0.32	0.32		0.57	0.20
S5M-I	0.59	0.81	0.45	0.58	0.82	0.31	0.71	0.44	0.29	0.43	0.25	0.70	0.53	0.69	0.47	0.57	0.50	0.57	0.34	0.29	0.28		0.51	0.18
S5H-I	0.57	0.79	0.43	0.56	0.79	0.30	0.69	0.43	0.28	0.42	0.24	0.67	0.52	0.67	0.46	0.55	0.49	0.56	0.33	0.28	0.28		0.49	0.17
C1L-I	0.67	0.93	0.51	0.66	0.93	0.36	0.82	0.51	0.33	0.49	0.29	0.80	0.61	0.79	0.54	0.65	0.57	0.66	0.39	0.33	0.33		0.58	0.20
C1M-I	0.60	0.83	0.46	0.59	0.83	0.32	0.73	0.45	0.29	0.44	0.26	0.71	0.54	0.70	0.48	0.58	0.51	0.58	0.34	0.29	0.29		0.52	0.18
C1H-I	0.74	1.02	0.56	0.72	1.02	0.39	0.89	0.55	0.36	0.54	0.31	0.87	0.67	0.86	0.59	0.71	0.62	0.71	0.42	0.36	0.35		0.63	0.22
C2L-I	0.59	0.81	0.45	0.57	0.81	0.31	0.71	0.44	0.29	0.43	0.25	0.69	0.53	0.69	0.47	0.57	0.50	0.57	0.34	0.28	0.28		0.50	0.17
C2M-I	0.51	0.71	0.39	0.50	0.71	0.27	0.62	0.39	0.25	0.38	0.22	0.61	0.47	0.60	0.41	0.50	0.44	0.50	0.30	0.25	0.25		0.44	0.15
C2H-I	0.49	0.68	0.38	0.48	0.68	0.26	0.60	0.37	0.24	0.36	0.21	0.58	0.45	0.58	0.40	0.48	0.42	0.48	0.28	0.24	0.24		0.42	0.15
C3L-I	0.72	0.99	0.54	0.70	0.99	0.38	0.87	0.54	0.35	0.52	0.30	0.84	0.65	0.84	0.58	0.69	0.61	0.70	0.41	0.35	0.35		0.61	0.21
C3M-I	0.66	0.91	0.50	0.64	0.91	0.35	0.80	0.50	0.32	0.48	0.28	0.78	0.60	0.77	0.53	0.64	0.56	0.64	0.38	0.32	0.32		0.57	0.20
C3H-I	0.65	0.90	0.50	0.64	0.90	0.35	0.79	0.49	0.32	0.48	0.28	0.77	0.59	0.77	0.53	0.63	0.56	0.64	0.38	0.32	0.32		0.56	0.19
PC1-I	0.65	0.89	0.49	0.63	0.89	0.34	0.78	0.49	0.32	0.47	0.27	0.76	0.58	0.76	0.52	0.63	0.55	0.63	0.37	0.31	0.31		0.55	0.19
PC2L-I	0.70	0.97	0.53	0.68	0.97	0.37	0.85	0.53	0.34	0.51	0.30	0.83	0.63	0.82	0.56	0.68	0.59	0.68	0.40	0.34	0.34		0.60	0.21
PC2M-I	0.62	0.85	0.47	0.60	0.86	0.33	0.75	0.47	0.30	0.45	0.26	0.73	0.56	0.73	0.50	0.60	0.52	0.60	0.35	0.30	0.30		0.53	0.18
PC2H-I	0.61	0.84	0.46	0.60	0.85	0.32	0.74	0.46	0.30	0.45	0.26	0.72	0.55	0.72	0.49	0.59	0.52	0.59	0.35	0.30	0.29		0.52	0.18
RM1L-I	0.58	0.80	0.44	0.56	0.80	0.30	0.70	0.43	0.28	0.42	0.25	0.68	0.52	0.68	0.46	0.56	0.49	0.56	0.33	0.28	0.28		0.50	0.17
RM1M-I	0.51	0.70	0.39	0.50	0.71	0.27	0.62	0.38	0.25	0.37	0.22	0.60	0.46	0.60	0.41	0.49	0.43	0.50	0.29	0.25	0.25		0.44	0.15
RM2L-I	0.57	0.79	0.43	0.56	0.79	0.30	0.69	0.43	0.28	0.42	0.24	0.67	0.52	0.67	0.46	0.55	0.48	0.56	0.33	0.28	0.28		0.49	0.17
RM2M-I	0.51	0.70	0.39	0.50	0.71	0.27	0.62	0.38	0.25	0.37	0.22	0.60	0.46	0.60	0.41	0.49	0.43	0.50	0.29	0.25	0.25		0.44	0.15
RM2H-I	0.52	0.71	0.39	0.50	0.71	0.27	0.62	0.39	0.25	0.38	0.22	0.61	0.47	0.61	0.41	0.50	0.44	0.50	0.30	0.25	0.25		0.44	0.15
URML-I	0.70	0.96	0.53	0.68	0.96	0.37	0.84	0.52	0.34	0.51	0.30	0.82	0.63	0.82	0.56	0.68	0.59	0.68	0.40	0.34	0.34		0.60	0.21
URMM-I	0.67	0.93	0.51	0.66	0.93	0.36	0.81	0.51	0.33	0.49	0.29	0.79	0.61	0.79	0.54	0.65	0.57	0.65	0.39	0.33	0.32		0.58	0.20
Mean	0.59	0.81	0.45	0.57	0.81	0.31	0.71	0.44	0.29	0.43	0.25	0.69	0.53	0.69	0.47	0.57	0.50	0.57	0.34	0.28	0.28		0.50	
Std. Dev.	0.09	0.13	0.07	0.09	0.13	0.05	0.11	0.07	0.05	0.07	0.04	0.11	0.08	0.11	0.07	0.09	0.08	0.09	0.05	0.05	0.04			0.19

V. Analysis

Site Conditions and Design Level Shaking

All 44 chosen locations offer a robust and diverse set of data for use in this study. The soil site classifications range from B to D for both high- and moderate-seismicity locations, as seen in Figure 19, and the shear wave velocities of the soil range from 186 meters per second to 760 meters per second. While there are noticeably less sites with site class B soil, this is representative of the limited amount of the United States with this level of shear wave velocity. Similarly, the S_{D1}-values for high-seismicity locations also include a wide spread of data, ranging from 0.192g to 1.183g for design-level MCE shaking and ranging from 0.211g to 1.113g for design-level MCE_R shaking. The moderate-seismicity locations are limited to a specific range of S_{D1}-values; however, the entire range of values is utilized for the study. The S_{D1}-values for these locations range from 0.065g to 0.195g for MCE shaking and ranging from 0.072g to 0.234g for MCE_R shaking. As such, this study does not just focus on a specific soil type or range of shaking values. The results from this study are representative of a variety of site conditions and shaking levels for several different high-seismicity and moderate-seismicity locations.

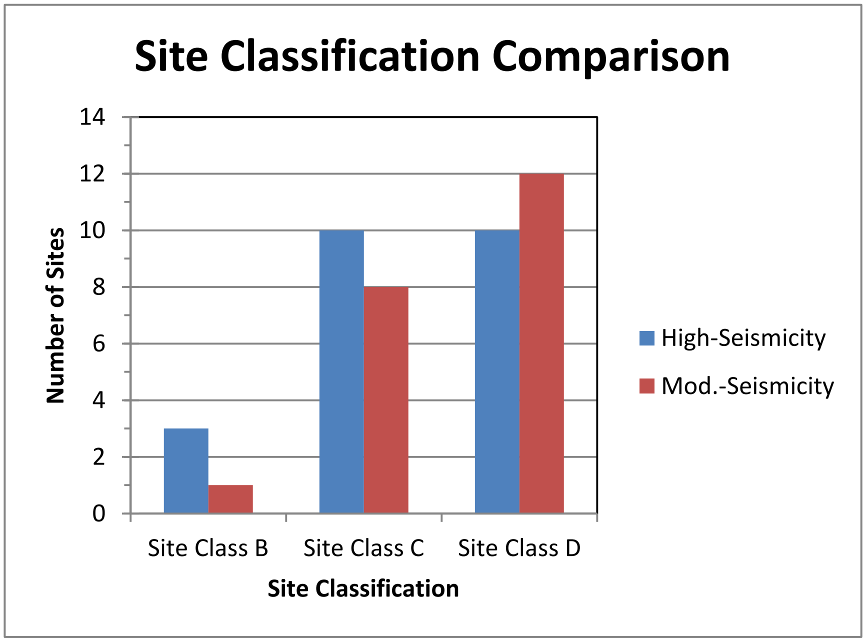

Figure 19. Site classification comparison for high- and moderate-seismicity locations

Fragility Curve Fitting

The lognormal cumulative distribution functions are calculated for each building type to create a representation of that building's fragility data. The purpose is to create a function such that the probability of collapse of that building type can be determined for any discrete spectral acceleration value. Based on the results from the standard and adjusted critical K.S. statistic values, all of the K.S. statistics fall below the standard 95th-percentile critical value by at least a factor of four and fall below the adjusted 95th-percentile critical value by at least a factor of two. The null hypothesis for the Kolmogorov-Smirnov test is that the sample data is drawn from the reference normal distribution. The results from the test prove that since all of the K.S. statistics do not exceed the critical K.S. statistic values, the test fails to reject the null hypothesis, and thus the curves are good fits.

High-Seismicity Locations

PMF and PMF' Analysis

Tables 16 and 17 from the results in Chapter IV each provide the reader with 805 different PMF and PMF' values, respectively. In order to analyze the data collectively, a single mean PMF and a single mean PMF', along with a corresponding standard deviation for all 805 values in each table, are calculated and presented in Table 34. Both mean values have a relatively close proximity to 0; however, the PMF' data produces a mean that is closer to 0 and a standard deviation that is lower than the PMF data.

Table 34. Mean performance modification factors for high-seismicity locations

Performance Modification Factors			
PMF		PMF'	
Mean	Std. Dev.	Mean	Std. Dev.
-0.20	0.59	0.03	0.50

As previously mentioned, a PMF or PMF’ of 0 represents identical scores produced through this study’s collapse fragility scoring procedure and its collapse risk scoring procedure. Having identical scores means that the 150-year collapse frequency of an existing building type in a specific location is comparable to the probability of collapse of that building type in that location subjected to design-level shaking. Since both the mean PMF and mean PMF’ are close in proximity to 0, this relationship is relatively true for both MCE and MCE_R design-level shaking values. Given the choice between the two sets of design values, however, MCE_R is preferred due to the lower standard deviation and mean value closer to 0 produced by the PMF’ data.

D and D’ Analysis

The average standard deviations of PMF and PMF’, however, are larger than originally expected. This means that while the mean PMF and PMF’ values are close to 0, the range of individual PMF and PMF’ values is somewhat wide. In general, higher and lower PMF and PMF’ values seem to be specific to locations with high and low S_{D1} values. In Luco et al. (2007), it is explained that the S_{M1} for each location is equal to the 10^{th}-percentile collapse capacity at that location. Based on the apparent relationship between S_{D1} and PMF, as well as the fact that S_{D1} is equal to $(2/3)S_{M1}$, it was hypothesized that the PMF and PMF’ values far from 0 are caused by situations in which the ratio of S_{M1} to $c_{10\%}$ (the average 10^{th}-percentile collapse capacity using existing building type fragility curves) strays from 1.0. This ratio is defined as D and D’. Figure 20 shows the relationship between PMF and D and Figure 21 shows the relationship between PMF’ and D’. Both plots show relationships that fit logarithmic curves relatively well, proving that PMF and PMF’ are indeed products of D and D’, and that higher

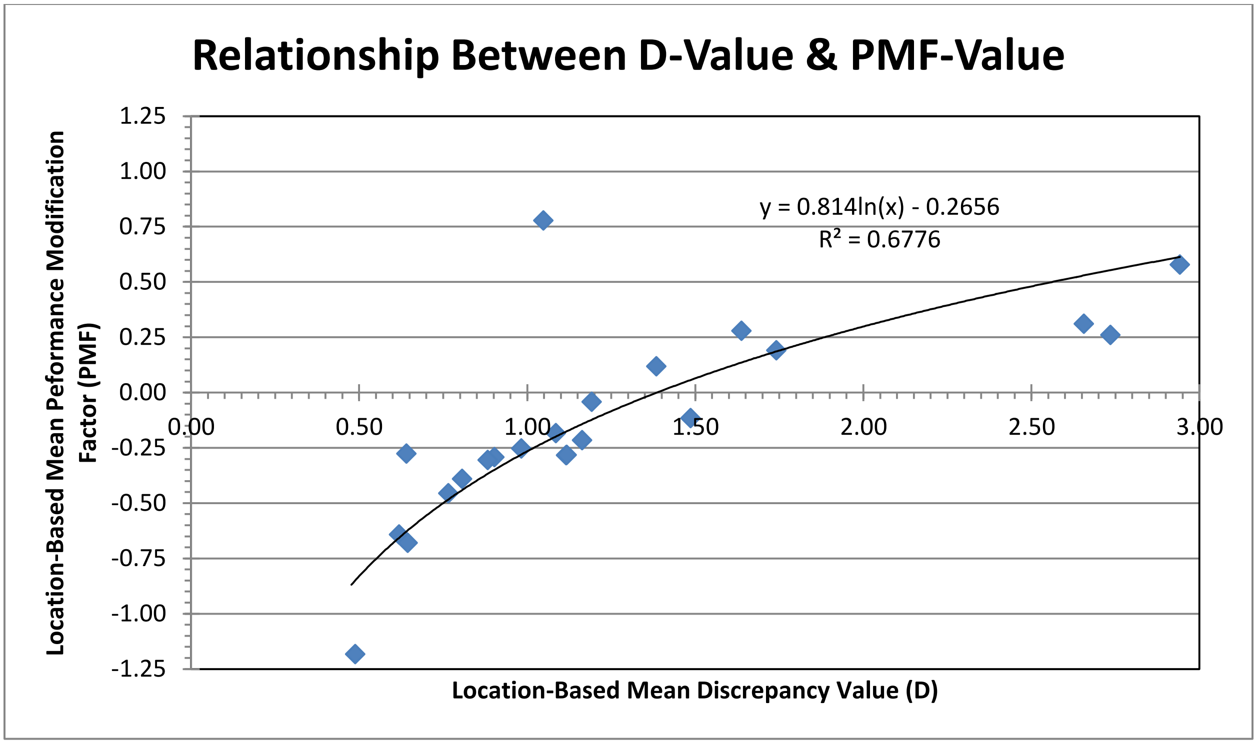

Figure 20. Plot of performance modification factor versus discrepancy value given MCE shaking for high-seismicity locations

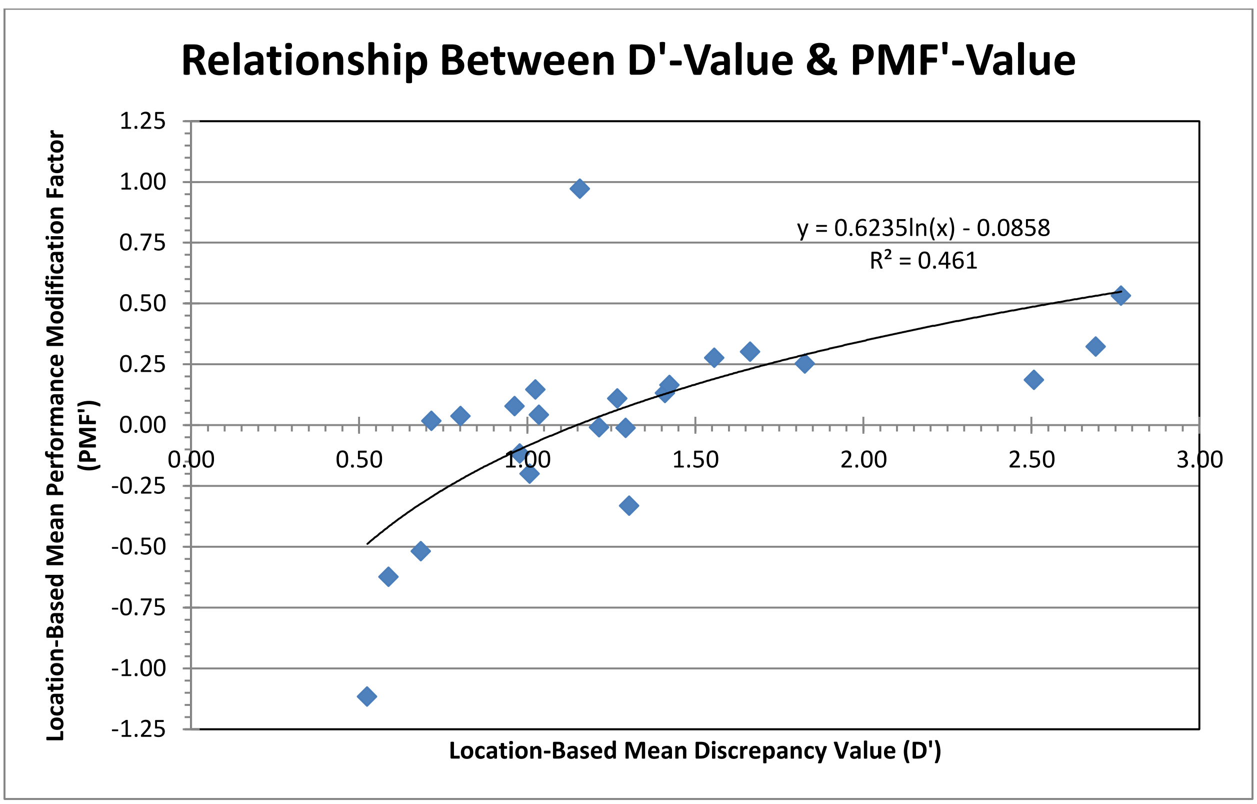

Figure 21. Plot of performance modification factor versus discrepancy value given MCE_R shaking for high-seismicity locations

and lower D and D' values may correspond to higher and lower PMF and PMF' values, respectively. As such, if the 10th-percentile collapse capacity of an existing building in a specific location is known, then the provided logarithmic curve equations could potentially be used to determine the expected PMF or PMF' value. That being said, this hypothesis is not fully developed and would require more research to be confirmed.

Moderate-Seismicity Locations

PMF and PMF' Analysis

Similar to the data collected for high-seismicity locations, Tables 30 and 31 provide the reader with 735 different PMF and PMF' values, respectively. Again, a single mean PMF and a single mean PMF', along with a corresponding standard deviation for the 735 values in each table, are calculated and presented in Table 35. Unlike the high-seismicity mean values, however, these mean values are much further from 0. Because of these results, the relationship between collapse fragility and collapse risk that exists for existing buildings in high-seismicity locations is not applicable to existing buildings in moderate-seismicity locations, regardless of the code level used for fragility curves.

Table 35. Mean performance modification factors for moderate-seismicity locations

Performance Modification Factors			
PMF		PMF'	
Mean	Std. Dev.	Mean	Std. Dev.
-1.73	1.06	-1.24	0.96

D and D' Analysis

The author felt it necessary, however, to complete the same analysis of D and D' for moderate-seismicity locations to explore whether the same relationship exists between D and PMF, as well as D' and PMF', as exists for high-seismicity locations. Figure 22 shows the relationship between PMF and D and Figure 23 shows the relationship between PMF' and D'.

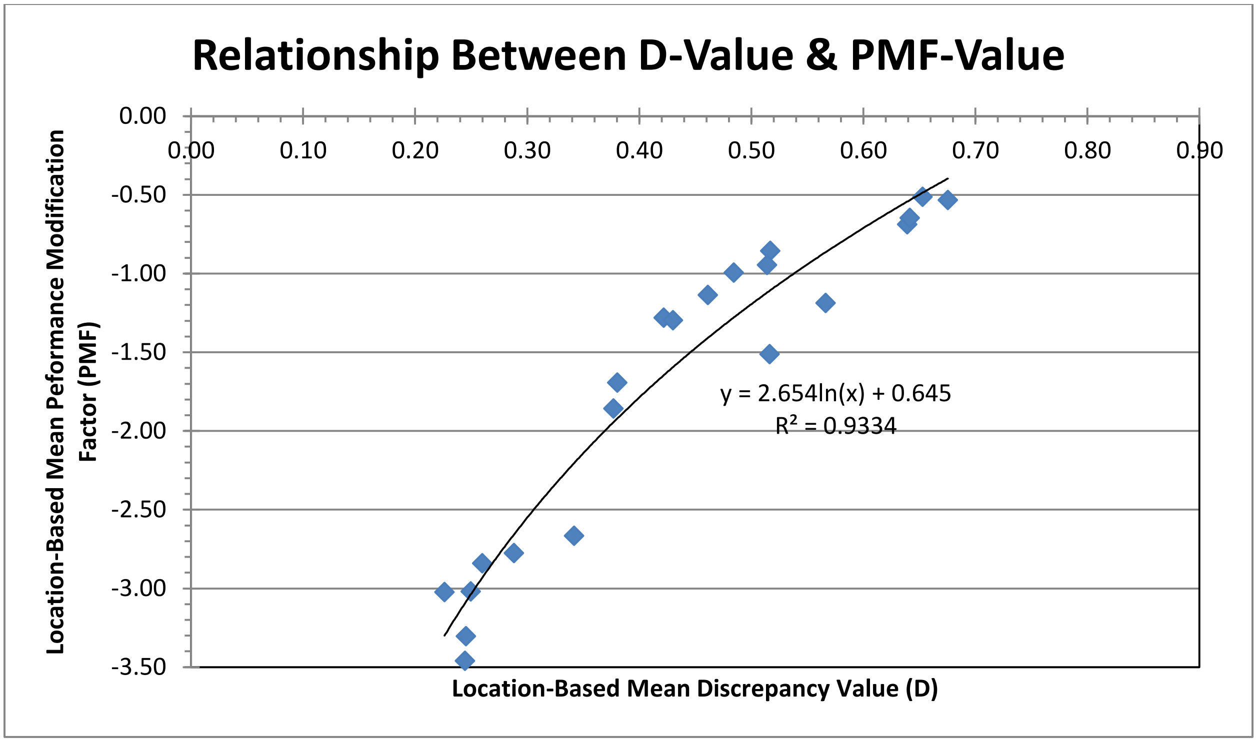

Figure 22. Plot of performance modification factor versus discrepancy value given MCE shaking for moderate-seismicity locations

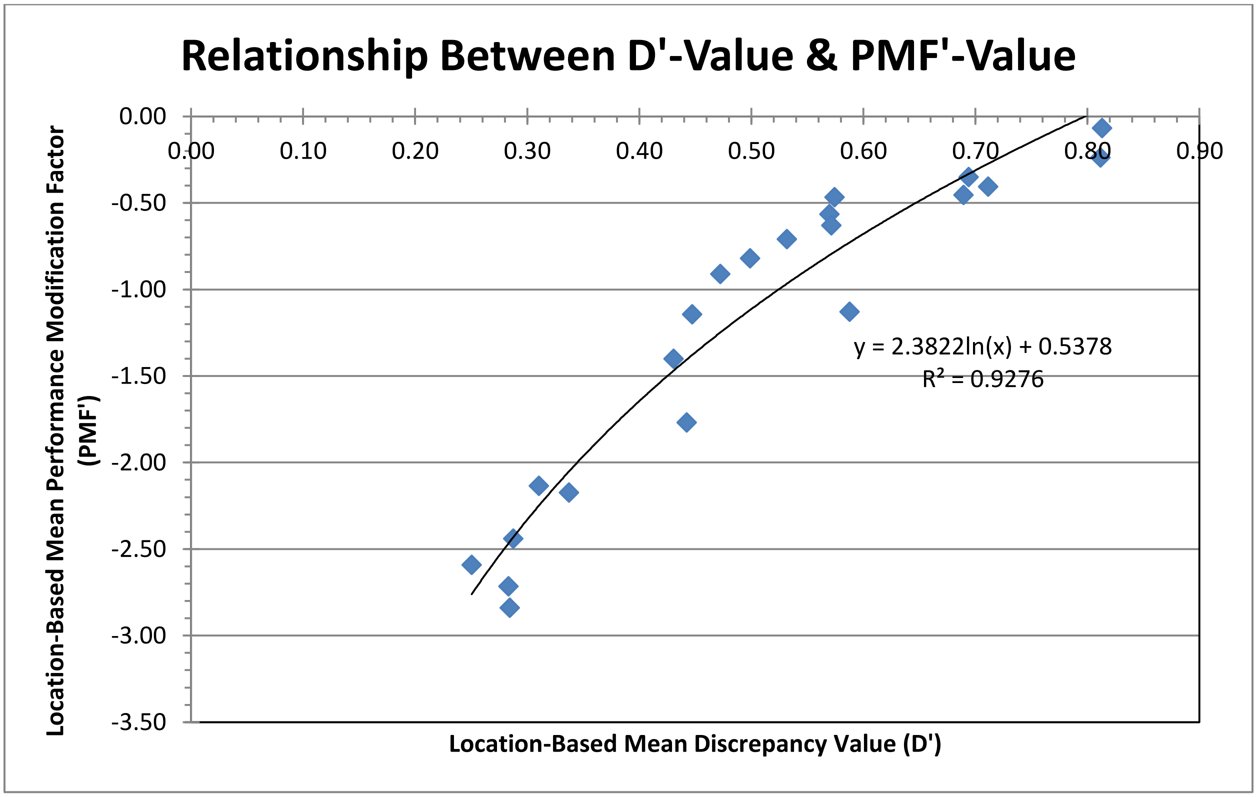

Figure 23. Plot of performance modification factor versus discrepancy value given MCE_R shaking for moderate-seismicity locations

Again, both plots show relationships that fit logarithmic curves, this time even better than the curves associated with the high-seismicity data. The logarithmic curve equations for the moderate-seismicity locations, however, include very different slope values than those for the high-seismicity data. As such, the specific relationship found between D and PMF for high-seismicity is again not applicable to moderate-seismicity locations. Again, this hypothesis is not fully developed and requires more research to be confirmed.

VI. Conclusion

For existing buildings located in regions of high seismicity, an identifiable relationship exists between collapse fragility and collapse risk. In this case, high seismicity regions are defined as regions in which S_{D1} design values exceed 0.20g, which is consistent with seismic design category D in ASCE 7-10 for risk category I, II, and III buildings. For an existing building type in these regions, the probability of collapse given design-level MCE or MCE_R shaking is comparable to the 150-year frequency of collapse of that building type in that location. This relationship, however, is not applicable to locations in which S_{D1} values fall between 0.067g and 0.20g. As S_{D1} values approach the 0.20g threshold between moderate and high seismicity, this relationship becomes less consistent. Furthermore, it seems that when the ratio of S_{M1} to the 10^{th}-percentile collapse capacity of the existing building type exceeds about 2.0, this relationship is again less consistent. Locations in which this ratio exceeds 2.0, however, are relatively rare, as they typically correspond to locations with very high design-level shaking values.

The existence of this identifiable relationship for most high seismicity locations, then, allows for two different interpretations of a single score assigned using FEMA 154. The score assigned to an existing building via FEMA 154 is the S-value in the following collapse probability equation:

$$P = 10^{-S}$$

where P = the probability of collapse given design-level shaking, or in this case, given shaking equivalent to S_{D1}. Using the relationship confirmed in this study, then, an S-score of 1 would not only represent a 10% probability of collapse given S_{D1} shaking, but would also represent a 0.1 collapses per 150 years for that existing building.

For an individual performing a rapid visual screening of an existing building, this information is much more useful. Though frequency is not necessarily equivalent to probability, this individual could analyze a 150-year frequency of collapse of 0.01 in a probabilistic way in an effort to compare earthquake risk to other known risks. In the example given, this individual could interpret an S-score of 1 to mean either a 10% probability of collapse within the next 150 years, or perhaps a 1% probability of collapse within the next 15 years. Overall, this relationship provides context and the opportunity to at least compare earthquake risk with other risks.

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