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Relationship Between Collapse Probability and Collapse Risk of New Buildings

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RELATIONSHIP BETWEEN COLLAPSE PROBABILITY AND COLLAPSE RISK OF NEW BUILDINGS

SUBMITTED BY

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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

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Relationship Between Collapse Probability and Collapse Risk of New Buildings

Thesis directed by Research Professor Keith A. Porter.

The main aim of this thesis is to find a relationship between collapse probability and collapse risk of new buildings. In this study, collapse probability is defined as the probability that a building will collapse when subjected to MCE_R shaking level ground motion at a location. Collapse risk is defined as the building collapse frequency over a period τ years due to shaking of any level at a location. FEMA P-695 fragility functions are used in this study to represent new buildings. Only reinforced concrete moment frame buildings with a period greater than 0.5s are considered for this. 23 high hazard locations and 21 medium hazard locations are selected across the United States to maintain uniformity in the comparison of collapse probability and collapse risk. Using the median collapse capacity and logarithmic standard deviation of collapse capacity of the building models taken from FEMA P-695, the collapse probabilities are calculated. A score is then calculated using a method similar to the one in FEMA 154. The overall annual risk to each building at each of the locations is calculated using a risk integral. Risk score is then calculated for a period of τ years. Scoring system allows us to uniformly compare the collapse probability and collapse risk and form a relationship between the two. Later, a sensitivity study is performed to check for variables that strongly influence this relationship.

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1. Introduction

Purpose of this Study

In the 2nd edition (current version) of FEMA 154, the probability that a building will collapse at a location when subjected to the MCE shaking level ground motion at that location is used to rapidly screen buildings for potential seismic hazard. For the next update of FEMA 154, we plan to propose frequency of building collapse over a period τ years at a location due to shaking of any level, here by referred to as collapse risk, also as a measure to rapidly evaluate the seismic hazard to buildings. This would help the audience (building officials and inspectors, government agencies, design professionals etc.) to quantify seismic hazard in terms of both collapse probability and collapse risk where collapse probability is defined as the probability that a building will collapse when subjected to MCE (or) MCE_R shaking level ground motion. Luco et al. (2007), in their study titled "Risk-Targeted versus Current Seismic Design Maps for the Conterminous United States", calculated risk-targeted mapped MCE ground motions (mapped MCE_R ground motions) for code-compliant buildings by adjusting the mapped MCE ground motions such that the collapse risk at a location is 1% in 50 years. FEMA P-695 is a code which recommends a methodology to reliably quantify building seismic performance and response parameters for use in seismic design. For this methodology, FEMA P-695 used code-compliant buildings such that the average probability of collapse due to MCE shaking level ground motions is less than 10%. Hence from Luco et. al.(2007) and FEMA P-695 study, we can see that collapse risk (for a 50 year period) is 0.1 times the collapse probability (due to MCE shaking level ground motions) for code-compliant buildings. Bretl (2014), in his study titled "Relationship Between the Collapse Fragility and Collapse Risk in Existing Buildings in Regions of High and Moderate Seismicity", checked if there is a similar relation for existing buildings. He arrived at a different relationship between collapse probability (due to MCE and MCE_R shaking level ground motions) and collapse risk (for a 150 year period) for existing buildings in high hazard regions. The main purpose of this study is to see if a similar relationship as developed by Bretl (2014) or seen in case of Luco et. al. (2007) and FEMA P-695 exists for new buildings at the same locations as picked by Bretl (2014). If a relationship does exist, then it is compared to the relation seen in Luco et.al. (2007) and FEMA P-695, and Bretl (2014) to check for uniformity of the results. The uncertainty in the collapse capacity is different in case of Luco et al. (2007) in contrast to Bretl (2014) and this study. Hence, this study also aims to see how strongly input variables influence the relationship between collapse probability and collapse risk. Bretl (2014) used fragility data from HAZUS-MH code for his study, which represents existing buildings. In this study, fragility functions from FEMA P-695 are considered which represent the new buildings. In this study collapse risk is calculated for both 50 year period (as used by Luco et. al. (2007)) and 150 year period (as used by Bretl (2014)).

Since there is a lot of terminology used in describing the calculation of collapse probability and collapse risk, a brief introduction of this terminology is provided in the following sections. In the first section several terms used in this study are defined. The second section addresses the updated version (latest as of this writing) of ASCE 7-05, the ASCE 7-10, in which an overview of the changes relating to this study is mentioned and other terms are defined. All the other terms used in this study which are not defined in these sections will be defined later in the study as and when they are introduced.

ASCE 7-05: Minimum Design Loads for Buildings and Other Structures

ASCE 7-05 provides minimum design requirements for buildings and other structures which are subject to code requirements. In ASCE 7-05, the mapped MCE spectral acceleration parameters at short period and 1 second period are defined as S_S and S_1 respectively. (Here and from here on, MCE is the abbreviation for maximum considered earthquake.) MCE ground motions values are defined as the ground motions which have 2% probability of exceedance in a 50 year period at a gridded location. ASCE 7-05 provides maps (Figures 22-1 through 22-14) which are used to determine the S_1 values for the following conditions – 5% damping and site class B. Section 11.4.2 and Chapter 20 of ASCE 7-05 classify a site, based on soil conditions, as site class A, B, C, D, E or F. S_1 values are adjusted to these site classes using site coefficients as follows-

$$S_{M1} = F_v S_1$$

Where,

F_v = long period site coefficient

S_{M1} = site class adjusted, 5% damped, MCE spectral response acceleration at 1 second period.

The design earthquake spectral response acceleration values, S_{DS} and S_{D1}, are calculated in accordance with section 11.4.4 as,

$$S_{D1} = \frac{2}{3} S_{M1}$$

Where,

S_{D1} = design earthquake spectral response acceleration at 1 second period.

In this study, we do not consider any buildings with a period less than 0.5 seconds because Charles Kircher, Project Technical Director of FEMA P-695 told in a private communication that he does not believe in the building models in FEMA P-695 with a period less than 0.5 seconds. Hence, we are only concerned with 1-second period spectral response acceleration values in this study.

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

ASCE 7-10 is the updated and latest version of ASCE 7 as of this writing. The significant change in ASCE 7-10 relating to this study is the definition of MCE. Here MCE_R is used rather than the previously used MCE. (Here and here on, MCE_R is the abbreviation for risk-targeted maximum considered earthquake.) At any location in the United States, mapped MCE_R ground motion values are the adjusted mapped MCE ground motions which result in a 1% probability of collapse in a 50 year period for code-compliant buildings. The updated S_1 values are determined using section 11.4.1 and Figures 22-2, 22-4, 22-5 and 22-6 of the ASCE 7-10. The procedure to determine SM_1 is similar to the procedure mentioned in ASCE 7-05.

The S_{M1} values are obtained using a USGS tool. This tool however requires that we specify a site class of a location along with its coordinates. Bretl (2014), in his study, has determined the site class for all the locations. Site class is determined using the shear wave velocity in the upper 30 meters of the soil, denoted by V_{s30}. A V_{s30} mapping tool is used to determine the velocities at each of the locations picked. Thus, after using these values in the USGS tool, we get the required S_{M1} values.

To calculate the S_{MT} values, which are building-specific S_{M1} values, the following equation is used-

$$S_{MT} = \frac{S_{M1}}{T}$$

Where,

S_{MT} = Building adjusted, 5 % damped, MCE_R spectral response acceleration value at building period T

In this study, we use building adjusted S_{M1} values to calculate the collapse probability of buildings. This is because the FEMA 154 also uses building adjusted S_{M1} values to calculate collapse probability of buildings. Hence, in this study, 'MCE_R shaking level ground motion' refers to the S_{MT} values at MCE_R shaking level.

2. Literature Review

Several parameters and methodologies like scoring system, hazard curves, risk-targeted maximum considered earthquake ground motions, fragility functions etc. are used in this study. The following literature review gives a brief idea about selection of these methodologies and parameters.

Luco, N. et al. (2007) - Risk-Targeted versus Current Seismic Design Maps for the Conterminous United States

A ground motion value with 2% probability of exceedance in 50 years was used in the probabilistic portions of the seismic design maps in NEHRP provisions, International Building code and ASCE 7-05. Luco et al. proposed to adjust the seismic design maps of ASCE 7-05 so that the new risk-targeted ground motions will lead to a collapse probability of 1% in 50 years. If a structure is designed according to uniform hazard ground motions (2% exceedance in 50 years), it would mean that the collapse capacity of the structure is exactly equal to the mapped value at the structure's location thereby leading to a uniformity in collapse probability of the structure. However, the collapse capacity of a structure always has uncertainty and hence the collapse probability of structure designed to uniform hazard requirements would not be uniform. They consider two sites, one representing western U.S. and the other representing eastern and central U.S. They use a logarithmic standard deviation of collapse capacity of 0.8 in the study as compared to an average value of 0.54 used in this study At these sites, they initially estimate the collapse probability for a 50 year period which are 1.1% and 0.7% respectively. This collapse probability was around 1% for 50 year period on an average when several locations over the United States were considered. Then, they back-calculated the ground motions values so that the probability of collapse would be 1% for a 50 year period. A risk coefficient (C_R) is proposed which adjusts the current mapped MCE values to obtain the mapped risk-targeted MCE values. This risk coefficient varies from 0.8 to 1.17 over the entire United States.

Bretl (2014) - Relationship Between the Collapse Fragility and Collapse Risk in Existing Buildings in Regions of High and Moderate Seismicity

Bretl performed a study to establish a relationship between collapse fragility (collapse probability) and collapse risk for existing buildings. He proposed that the collapse probability of an existing building subjected to design-level MCE shaking is nearly equal to its 150 year collapse frequency value, in case of high seismicity locations. When medium seismicity locations are considered, this relationship was not seen for the existing buildings. For his study, he picked 44 locations from across the United States of which 23 were from high seismicity regions and 21 from medium seismicity regions to maintain consistency in the results. He used Porter's (2009) HAZUS-MH based fragility functions for this study. HAZUS-MH is a Federal Emergency Management Agency's (FEMA) methodology for estimating potential losses from disasters. The logarithmic standard deviation of collapse capacity was 0.521 on average in his study as compared to an average of 0.8 in Luco's study and 0.54 used in this study. He considered both MCE and MCE_R shaking levels in his study.

Both Bretl (2014) and Luco et al. (2007) assumed that collapse capacity can be modeled by assuming a lognormal cumulative distribution function i.e. they calculated collapse probability using a lognormal cumulative distribution function.

FEMA P-695 - Quantification of Building Seismic Performance Factors

ATC (2009) provides a methodology to reliably quantify the building system performance and response parameters for use in seismic design. This methodology is used to establish the global seismic performance factors (SPFs), which includes the response modification factor (R factor), the system over strength factor (Ω_o) and deflection amplification factor (C_d). This methodology is used to determine the seismic response factors for design of seismic force resisting systems in new buildings. This methodology requires that the seismic force resisting system comply with all the applicable requirements in ASCE 7-05. Chapter 9 of FEMA P-695 introduces concrete special and ordinary building frame models that comply with requirements of ACI 318-05: *Building code requirements for structural concrete.* These building models are designed so that their probability of collapse is 10% on an average when subjected to MCE shaking level ground motion.

In this study, we intend to compare collapse risk and collapse probability values for new buildings. Hence, the fragility functions from Chapter 9 of FEMA P-695 are used in this study. Wood frame building models and building models with a period less than 0.5 seconds are not considered in this study. This is because, Charles Kircher, Project Technical Director of FEMA P-695 told in a private communication that he does not believe in the wood frame building models and other building frame models with a period less than 0.5 seconds, in FEMA P-695.

FEMA 154 – Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA 154, as the name suggests, is a code used for rapid visual screening of buildings to evaluate for potential seismic hazards. This code follows a sidewalk approach for evaluating the seismic hazard of buildings. Data collection forms are provided for high, low and seismic hazard locations. Each of these forms have a basic structural hazard score and score modifiers. Basic structural hazard score depends on the building type. Hence one needs to have an experienced eye to correctly judge the building type. Then the score modifiers are noted down depending on the height of building, site class of building location, occupancy of building, vertical irregularities etc. A final score is calculated by adding the basic structural hazard score and the score modifiers. This final score has a range of 0-7 where a higher score indicates lower collapse probability due to MCE ground motion and vice-versa. Final score of value 2 is used as a cut-off to evaluate the seismic hazard. Any building with a final score less than 2 needs to be evaluated in further detail for potential seismic hazards. All the above mentioned scores represent the collapse probability of the building should a design-level ground shaking occur. The relation between score and collapse probability is given as,

$$S = -log_{10}(C.P)$$

S is the score and C.P is the Collapse probability of the building should an MCE level shaking occur. This scoring methodology is used in this study in an effort to uniformly compare collapse probability and collapse risk. All the logarithms used in this study are to the base 10 except for the logarithmic standard deviation of collapse capacity of buildings. FEMA P-695 calculates the logarithmic standard deviation of collapse capacity using a natural logarithm.

United States Geological Survey (USGS) Hazard Curves (2008)

In order to calculate the collapse risk, we need the hazard curves at each of the locations picked. The United States Geological Survey (USGS) website has the hazard curves calculated on a grid of sites all over the United States. The 2008 USGS national seismic hazard maps show the ground motions for all probability levels across the United States. These maps are developed using the hazard curves. In this study, the 2008 hazard curves are used for the conterminous 48 states and 2007 hazard curves are used for locations in Alaska. The hazard curves are provided in the form of rectangular gridded data in 0.05° increments in latitude and longitude. The hazard curves contain the all probable ground motion values at a location expressed in units of 'g' (acceleration due to gravity) and their mean annual frequencies of exceedance. These hazard curves are available for various periods of the buildings. In this study, hazard curves corresponding to the 1-second period are used.

3. Data collection

Locations

Bretl (2014) picked the following locations for his study. This section introduces the thought process that went behind picking these locations. A total of 44 locations are picked from across the United States, to maintain uniformity in the results of the study. Of these 44 locations, 23 locations are from high hazard regions and 21 from medium hazard regions. Table 4-1 of FEMA 155, as shown below in Table 1, has been used to classify a region to be high hazard or medium hazard. Only 1 second spectral response accelerations are considered in this study.

Table 4-1 Criteria Specifying Seismicity Region as a Function of Short-Period and Long-Period Spectral Acceleration Response

Region of Seismicity	*Short Period (0.2 sec) Spectral Acceleration Response*	*Long Period (1.0 sec) Spectral Acceleration Response*
Low	< 0.167g	< 0.067g
Moderate	0.167g to 0.500g	0.067g to 0.200g
High	≥ 0.500g	≥ 0.200g

Table 1: Classification of locations as high or medium hazard (taken from FEMA P155)

As mentioned in Table 1, a high hazard location is one which has a mapped 1 second Spectral acceleration response of >0.2g. (Here and from here on ‘g’ represents the acceleration due to gravity.) Similarly, if the mapped 1 second spectral acceleration value at a location is between the range of 0.067g-0.2g then that location is classified as a medium hazard location.

All the locations picked were from densely populated areas and hence the main purpose of NEHRP provisions, to avoid serious injury and life loss, is maintained. Tables 2 and 3 show the place, state and the gridded information of the locations chosen. Figure 1 shows the locations picked on a United States map. This Figure differentiates between high hazard and medium hazard locations by using different colored pins wherein red colored pin indicates high hazard region and yellow colored pin indicates a medium hazard location. Locations picked from Anchorage, Alaska are not shown in this Figure.

High hazard locations					
Location number	Location	State	Placemark number	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	40.65	-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

Table 2 : High hazard locations

Medium hazard locations					
Location number	Location	State	Placemark number	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	38.65	-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

Table 3 : Medium hazard locations

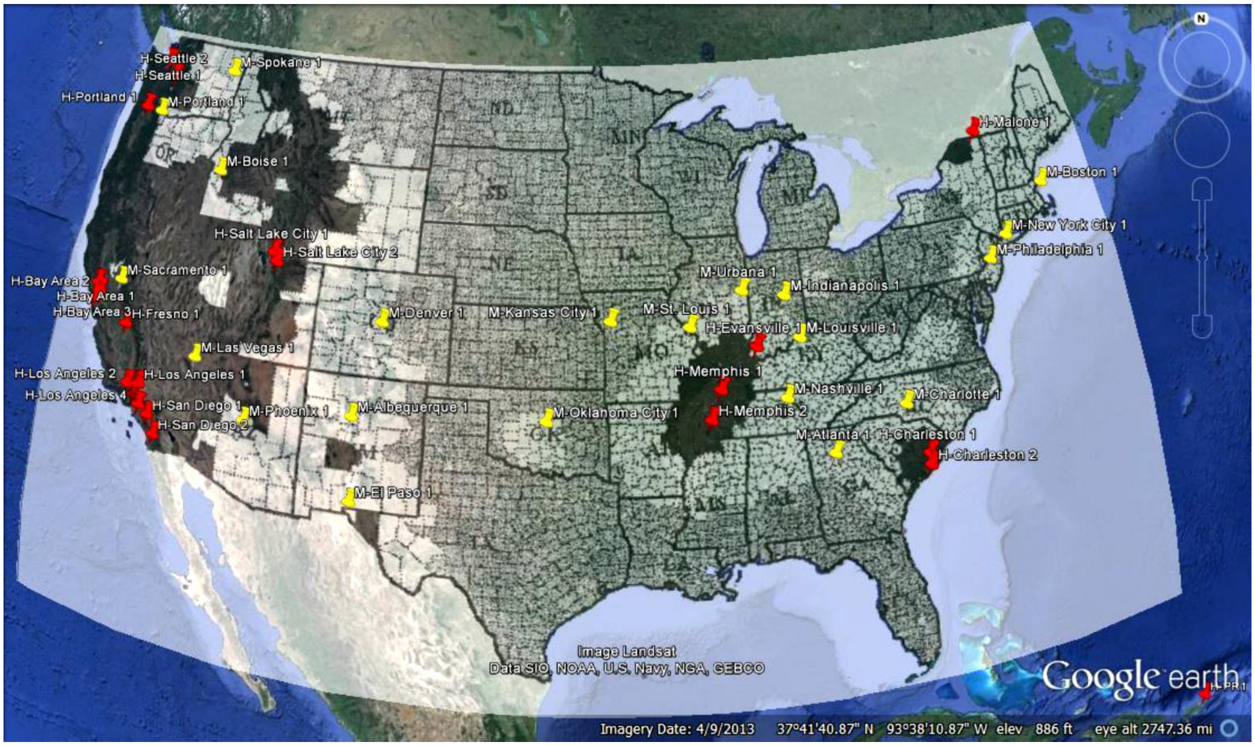

Figure 1: High hazard and medium hazard locations on a map (excluding locations in Alaska)

Red pins – High hazard locations; Yellow pins– Medium hazard locations

Building Fragility Functions

To evaluate the collapse probability and collapse risk, we need to know the median collapse capacities (θ) and logarithmic standard deviations of collapse capacity (β) of all the building types chosen for this study. The θ and β values are taken directly from FEMA P-695 (see Table 5).

FEMA P-695 uses incremental dynamic analysis (IDA) to calculate the median collapse capacities of the buildings. Incremental dynamic analysis is a concept in which the intensities of ground motions are increased by scaling until the structure collapses. For calculating the median collapse capacity, the Far-Field data set is set at MCE intensity level adjusted for the building period. The intensities of these ground motions are then increased until one-half of the records yield collapse of building. The lowest ground motion intensity level at which one-half of the scaled records yield building collapse is the median collapse capacity.

Simulated and non-simulated collapse modes are considered by FEMA P-695 for evaluating collapse capacities of building models. The reinforced concrete special moment frame buildings are assumed to collapse in a sideway mechanism and simulations are performed. This assumption is made because of the detailing, continuity and capacity design provisions prevent other collapse modes. For reinforced concrete ordinary moment frames where the additional modes of failure i.e. non-simulated collapse modes (like column shear failure, loss of gravity-load bearing capacity etc.) should be accounted for, component limit state checks are used.

For calculating the logarithmic standard deviation of the collapse capacity of building models, FEMA P-695 considers the following criteria – record to record uncertainty (β_{RTR}), uncertainty of non linear structural modeling (β_{MDL}), the quality of data used to calibrate element models (β_{TD}) and the quality of structural system design requirements (β_{DR}). Each of these criteria has different levels of rating - (A) Superior, (B) Good, (C) Fair or (D) Poor. Depending on the rating for each of the above mentioned criteria, a total system logarithmic standard deviation value (β_{TOT}) is calculated as,

$$\beta_{TOT} = \sqrt{\beta_{RTR}^2 + \beta_{DR}^2 + \beta_{TD}^2 + \beta_{MDL}^2}$$

A sample calculation of β_{TOT} is shown below for a better understanding. Record to record uncertainty is calculated based on period based ductility (μ_T). If the μ_T value is greater than or equal to 3, then β_{RTR} is assumed to be 0.4. If not, it is calculated using the following expression-

$$\beta_{RTR} = 0.1 + 0.1\mu_T \leq 0.4$$

where β_{RTR} must be greater than or equal to 0.2

Based on this value of β_{RTR} of 0.4 and for Model Quality β_{MDL} = (A) Superior, Table 4 taken from FEMA P-695 shows the calculation of β_{TOT}. Hence for (B) Good quality of test data and design requirements, β_{TOT} = 0.5.

Table 7-2a Total System Collapse Uncertainty (β_{TOT}) for Model Quality (A) Superior and Period-Based Ductility, $\mu_T \geq 3$

Quality of Test Data	Quality of Design Requirements			
	(A) Superior	(B) Good	(C) Fair	(D) Poor
(A) Superior	0.425	0.475	0.550	0.650
(B) Good	0.475	0.500	0.575	0.675
(C) Fair	0.550	0.575	0.650	0.725
(D) Poor	0.650	0.675	0.725	0.825

Table 4 : Calculation of β_{TOT} given β_{RTR} = 0.4 and β_{MDL} = (A) Superior

Similarly, tables 7-2b, 7-2c and 7-2d of FEMA P-695 show the calculations of β_{TOT} for model quality (B) Good, (C) Fair and (D) Poor respectively.

The fundamental period of buildings (T) is necessary to calculate the S_{MT} values for buildings at each location. The fundamental periods of building are taken from FEMA P-695. It calculates the fundamental period as,

$$T_a = C_t h_n^x$$

$$T = C_u T_a \geq 0.25s$$

Where,

h_n = height of the building in feet.

C_u = Coefficient for upper limit on calculated period (Table 12.8-1 of ASCE 7-05)

C_t and x = Approximate period parameters (Table 12.8-2 of ASCE 7-05)

Ta = Approximate period of the building.

Building fragility data from FEMA P-695						
Model type	Archetype ID	No. of Stories	FEMA 154 height category	T(s)	Median Collapse capacity-θ (S_{MT} -g)	Logarithmic standard deviation of collapse capacity-β (ln(g))
CSMF	1003	4	Mid-Rise	0.81	1.79	0.5
CSMF	1011	8	High-Rise	1.49	0.75	0.5
CSMF	5013	12	High-Rise	2.13	0.61	0.5
CSMF	5020	20	High-Rise	3.36	0.45	0.5
CSMF	1008	4	Mid-Rise	0.81	1.98	0.5
CSMF	1012	8	High-Rise	1.49	0.98	0.5
CSMF	5014	12	High-Rise	2.13	0.67	0.5
CSMF	5021	20	High-Rise	3.36	0.53	0.5
CSMF	6011	8	High-Rise	1.6	0.29	0.5
CSMF	6013	12	High-Rise	2.28	0.23	0.5
CSMF	6020	20	High-Rise	3.6	0.17	0.5
CSMF	6021	20	High-Rise	3.6	0.27	0.5
COMF	1009	4	Mid-Rise	1.03	2.06	0.5
COMF	1010	4	Mid-Rise	1.03	2.60	0.5
COMF	9101	2	Low Rise	0.55	0.89	0.575
COMF	9103	4	Mid-Rise	0.99	0.31	0.575
COMF	9105	8	High-Rise	1.81	0.15	0.575
COMF	9107	12	High-Rise	2.59	0.12	0.575
COMF	9102	2	Low Rise	0.55	0.72	0.575
COMF	9104	4	Mid-Rise	0.99	0.28	0.575
COMF	9106	8	High-Rise	1.81	0.26	0.575
COMF	9108	12	High-Rise	2.59	0.17	0.575
COMF	9201	2	Low Rise	0.51	0.80	0.575
COMF	9203	4	Mid-Rise	0.93	0.44	0.575
COMF	9205	8	High-Rise	1.7	0.20	0.575
COMF	9207	12	High-Rise	2.44	0.15	0.575
COMF	9202	2	Low Rise	0.51	0.70	0.575
COMF	9204	4	Mid-Rise	0.93	0.46	0.575
COMF	9206	8	High-Rise	1.7	0.30	0.575
COMF	9208	12	High-Rise	2.44	0.16	0.575

Table 5 : Fragility functions of buildings from FEMA P-695

4. Procedure

This chapter describes the calculation of collapse probability, collapse risk, score, risk score and PMF_R.

Calculation of Collapse Probability

Collapse probability of a building at a location is calculated using a lognormal cumulative distribution function. This calculates the probability that a building with a median collapse capacity of θ and a logarithmic standard deviation of collapse capacity β will collapse when subjected to the MCE_R S_{MT} value at that particular location. Figure 3 shows a fragility function which is formed by calculating collapse probabilities at various levels of shaking x (g). Figure 3 shows probability of collapse of building at various levels of shaking but we are only interested in the collapse probability at MCE_R S_{MT} shaking level ground motion,

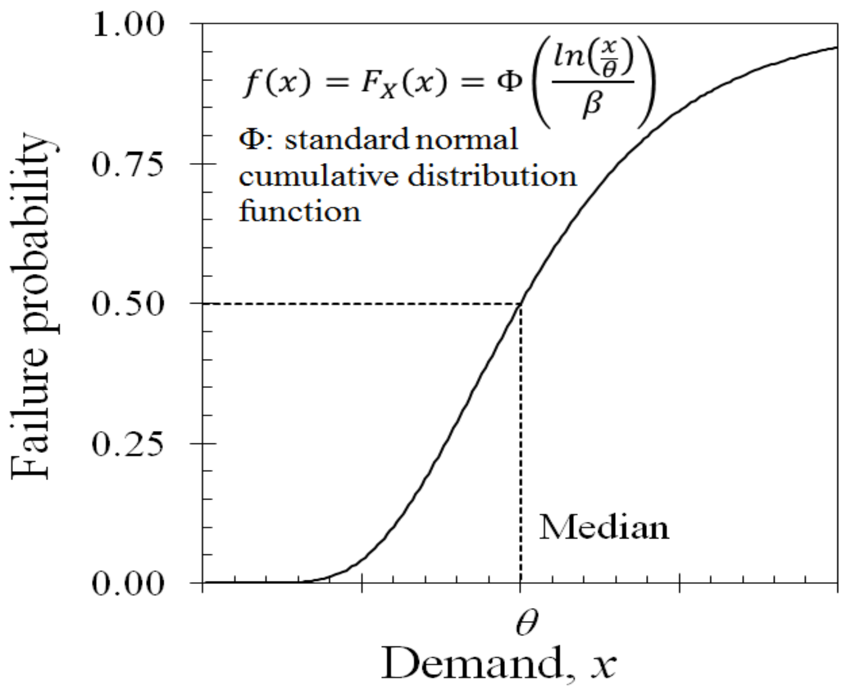

Figure 2: Pictorial representation of a fragility function (Porter (2014))

For this study, the variables in the figure above can be explained as,

x = MCE_R S_{MT} intensity value (g)

$F_x(x)$ = Collapse probability conditioned on MCE_R shaking level

θ and β = median collapse capacity and logarithmic standard deviation of collapse capacity of building models

In order to compare the collapse probability and collapse risk, a scoring system similar to the one shown in FEMA 154, has been adopted in this study.

Calculation of Score

In this study, score (S) is defined as the negative logarithm of the collapse probability of the building at a given location. The logarithms used while calculating score and risk score are all to the base 10. To explain score, a score of 2 indicates a 1 in 100 chance for collapse of the building while a score of 3 indicates a 1 in 1000 chance for the collapse of building.

$$S = -log_{10}(C.P)$$

Where,

C.P = Collapse probability of the building conditioned on MCE_R S_{MT} level shaking

Hazard Curves

In order to calculate the collapse risk at the locations, we need the hazard curves. Hazard curves can be obtained directly from the USGS website. For the conterminous 48 states in which we have most of the locations, 2008 hazard curves were used as it was the latest at the time.

Currently, latest version for the conterminous 48 states is 2014 hazard curves. For locations in Alaska and Puerto Rico, 2007 hazard curves were used since they are the latest version.

The location details are mentioned in terms of latitudes and longitudes. USGS website gives us the hazard curves in terms of intensity levels (units of ‘g’-acceleration due to gravity) and their mean annual frequencies of exceedance for each location. The hazard curves are available for short period and 1- second period spectral response acceleration and in this study the 1 second period spectral response acceleration values are considered.

This hazard curves are for a boundary B/C site class condition i.e at a V_{s30} value of 760 m/s. Hence, the hazard curves are adjusted for all the site classes depending on the F_v value calculated at each of these locations. The F_v value for a B/C boundary site class is 1.0. The fragility curves for high and medium hazard locations are shown in Figures 4 and 5.

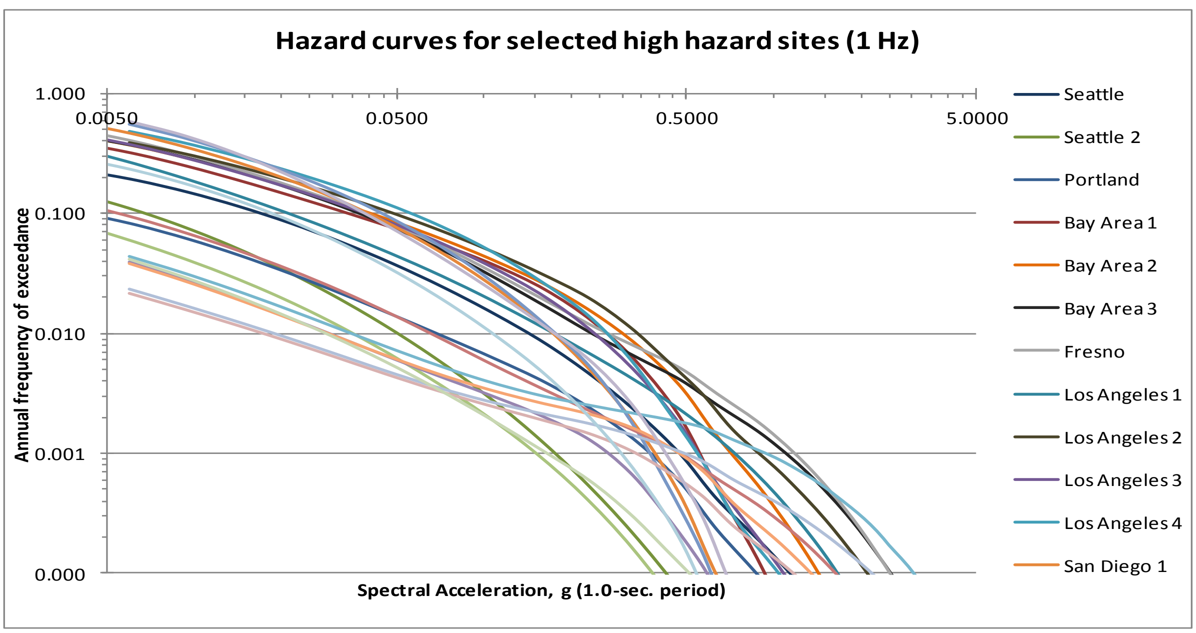

Figure 3: Hazard curves for selected high hazard sites (1Hz)

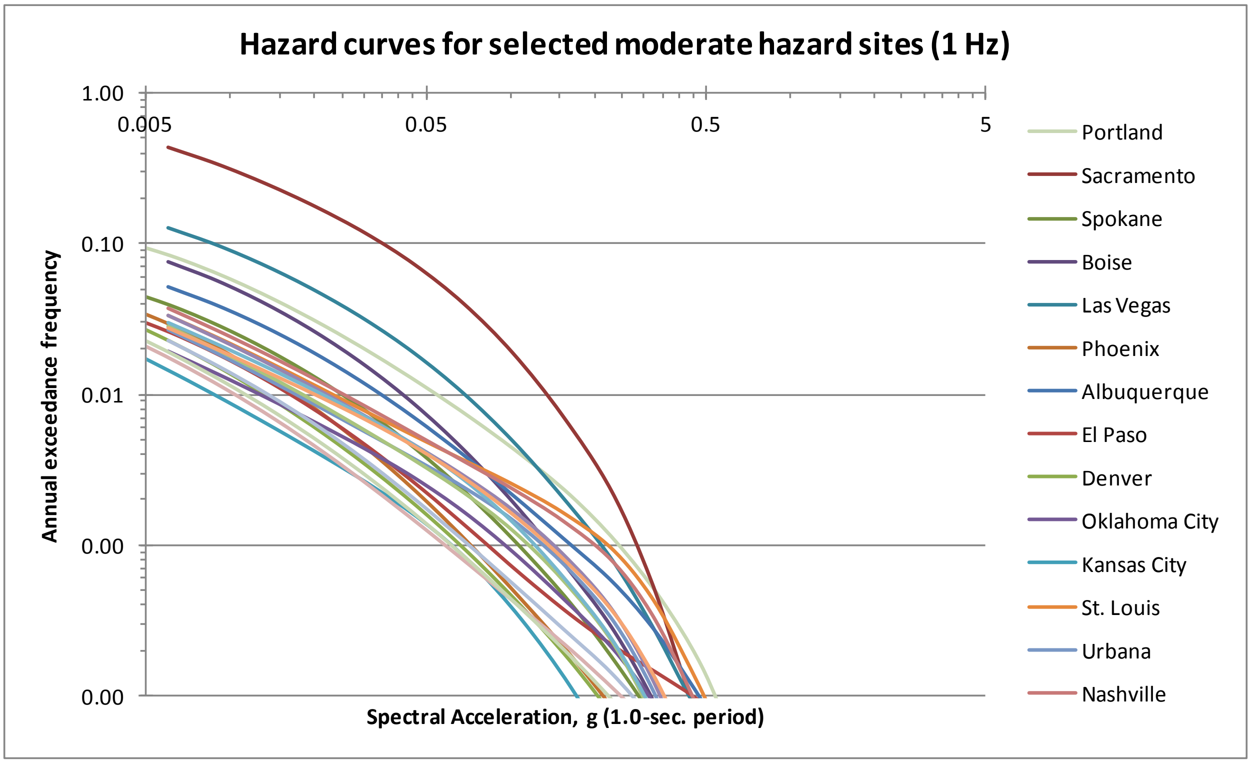

Figure 4: Hazard curves for selected moderate hazard sites (1Hz)

Calculation of Collapse Risk

Hazard curves give us several ground motion shaking levels and their mean annual frequencies of exceedance. Frequency of collapse of a building due to a particular value of ground motion intensity indicates the risk to the building from that ground motion intensity. Collapse risk to a building at a location is annual frequency of collapse of the building from all such ground motion intensities considered in this study (hazard curves). The risk integral to calculate the collapse risk is given as,

$$\lambda = \int_{x=0}^{\infty} -F(x)\frac{dG(x)}{dx}dx$$

This integral is solved numerically using an equation from Porter et al. (2006) stated as follows,

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

$$\Delta x_i = x_i - x_{i-1} \qquad \Delta F_i = F_i - F_{i-1} \qquad m_i = \ln(G_i / G_{i-1}) / \Delta x_i$$

Where,

F(x) = Fragility function solved at a ground motion intensity level x (refer to Collapse probability section for more information on fragility functions)

G(x) = Annual exceedance frequency at a shaking level

λ = Overall annual collapse risk (frequency of building collapse in an year)

x = Ground motion intensity (g)

Calculation of Risk Score

Similar to score, risk score is defined as the negative logarithm of multiplication of the overall collapse risk to a building at a location and period of interest τ. This period τ indicates the period over which the collapse risk to a building is desired. In this study, τ values of 50 years and 150 years are used. 50 years denotes the period in which earthquake of all possible ground motion intensities may occur while 150 years is assumed to be the realistic life-span of the buildings. Hence, the equation to calculate risk score is given as,

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

To explain risk score, a risk score of 3 indicates 1/1000 collapses for a given period τ while a risk score of 2 indicates 1/100 collapses for the same period τ.

Comparison of Score and Risk Score

Score and risk score, i.e. collapse probability and collapse risk are compared using a parameter called PMF_R. PMF_R stands for risk-targeted performance modification factor. PMF_R is computed as,

$$PMF_R = S_R - S$$

To define, a PMF_R value of 1 indicates that, for a building model at a particular location, the frequency of collapse over a period τ conditioned on hazard curves of a location is 1/10th of its collapse probability conditioned on MCE_R S_{MT} level shaking.

5. Results & Discussion

V_{s30} and Site Soil Classification

Table 7 and Table 8 show the V_{s30} values and the site classes for high hazard and moderate hazard locations respectively.

High hazard locations					
Location number	Location	State	V_{s30} (m/s)	V_{s30} (ft/s)	Site class
1	Seattle	WA	469	1539	C
2	Seattle	WA	760	2493	B
3	Portland	OR	546	1791	C
4	Bay Area	CA	391	1283	C
5	Bay Area	CA	437	1434	C
6	Bay Area	CA	721	2365	C
7	Fresno	CA	754	2474	C
8	Los Angeles	CA	760	2493	B
9	Los Angeles	CA	194	636	D
10	Los Angeles	CA	466	1529	C
11	Los Angeles	CA	206	676	D
12	San Diego	CA	599	1965	C
13	San Diego	CA	276	906	D
14	Salt Lake City	UT	454	1490	C
15	Salt Lake City	UT	718	2356	C
16	Evansville	IN	297	974	D
17	Memphis	TN	237	778	D
18	Memphis	TN	212	696	D
19	Charleston	SC	207	679	D
20	Charleston	SC	250	820	D
21	Malone	NY	322	1056	D
22	San Juan	PR	272	892	D
23	Anchorage	AK	760	2493	B

Table 6 : V_{s30} and site soil classes for high hazard locations

Medium hazard locations					
Location number	Location	State	V_{s30} (m/s)	V_{s30} (ft/s)	Site class
1	Portland	OR	760	2493	B
2	Sacramento	CA	456	1496	C
3	Spokane	WA	442	1450	C
4	Boise	ID	258	846	D
5	Las Vegas	NV	287	942	D
6	Phoenix	AZ	380	1247	C
7	Albuquerque	NM	186	610	D
8	El Paso	TX	536	1759	C
9	Denver	CO	549	1801	C
10	Oklahoma City	OK	222	728	D
11	Kansas City	MO	375	1230	C
12	St. Louis	MO	306	1004	D
13	Urbana	IL	248	814	D
14	Nashville	TN	315	1033	D
15	Indianapolis	IN	207	679	D
16	Louisville	KY	302	991	D
17	Atlanta	GA	285	935	D
18	Charlotte	NC	281	922	D
19	Philadelphia	PA	281	922	D
20	New York	NY	506	1660	C
21	Boston	MA	371	1217	C

Table 7 : V_{s30} and site soil classes for medium hazard locations

Risk-Targeted Spectral Response Acceleration

The site class adjusted risk targeted spectral response acceleration values (S_{M1}) are computed using procedures shown in Chapter 4. Table 6 contains site class adjusted risk targeted spectral response acceleration values for high hazard locations and Table 7 contains site class adjusted risk targeted spectral response acceleration values for medium hazard locations.

S_{M1} - High hazard locations					
Location number	Location	State	S_1 (g)	F_V	S_{M1} (g)
1	Seattle	WA	0.589	1.30	0.765
2	Seattle	WA	0.311	1.00	0.311
3	Portland	OR	0.431	1.37	0.590
4	Bay Area	CA	0.600	1.30	0.780
5	Bay Area	CA	0.605	1.30	0.787
6	Bay Area	CA	1.249	1.30	1.624
7	Fresno	CA	1.164	1.30	1.513
8	Los Angeles	CA	1.102	1.00	1.102
9	Los Angeles	CA	0.256	1.89	0.484
10	Los Angeles	CA	0.723	1.30	0.939
11	Los Angeles	CA	0.567	1.50	0.851
12	San Diego	CA	0.462	1.34	0.618
13	San Diego	CA	0.336	1.73	0.581
14	Salt Lake City	UT	0.661	1.30	0.859
15	Salt Lake City	UT	0.265	1.00	0.265
16	Evansville	IN	0.208	1.98	0.413
17	Memphis	TN	1.113	1.50	1.670
18	Memphis	TN	0.483	1.52	0.732
19	Charleston	SC	0.669	1.50	1.004
20	Charleston	SC	0.363	1.67	0.608
21	Malone	NY	0.142	2.23	0.316
22	San Juan	PR	0.382	1.64	0.625
23	Anchorage	AK	0.698	1.30	0.907

Table 8 : S_{M1} values at MCE_R intensity level for high hazard locations

S_{M1} - Medium hazard locations					
Location number	Location	State	S_1 (g)	F_V	S_{M1} (g)
1	Portland	OR	0.258	1.54	0.398
2	Sacramento	CA	0.238	1.93	0.457
3	Spokane	WA	0.115	1.69	0.193
4	Boise	ID	0.104	2.38	0.248
5	Las Vegas	NV	0.164	2.14	0.352
6	Phoenix	AZ	0.079	1.70	0.134
7	Albuquerque	NM	0.137	2.25	0.308
8	El Paso	TX	0.113	1.69	0.191
9	Denver	CO	0.073	1.70	0.124
10	Oklahoma City	OK	0.078	2.40	0.186
11	Kansas City	MO	0.064	1.70	0.108
12	St. Louis	MO	0.162	2.15	0.349
13	Urbana	IL	0.096	2.40	0.230
14	Nashville	TN	0.146	2.22	0.323
15	Indianapolis	IN	0.085	2.40	0.204
16	Louisville	KY	0.103	2.39	0.246
17	Atlanta	GA	0.090	2.40	0.216
18	Charlotte	NC	0.104	2.39	0.247
19	Philadelphia	PA	0.061	2.40	0.146
20	New York	NY	0.072	1.70	0.123
21	Boston	MA	0.072	1.70	0.123

Table 9 : S_{M1} values at MCE_R intensity level for medium hazard locations

The following tables show the collapse probabilities, collapse risks, scores, risk scores and PMF_R values for the buildings at high hazard locations. Table 12 shows the score calculated using collapse probabilities at high hazard locations. This table is color coded so that as the color varies from red color for the lowest value of score in the table to green color which is the highest value of score in the table. This representation is chosen to show that a lower value of score represents a higher probability of collapse under MCE_R shaking level ground motion. In the table, we can see that the collapse probabilities of COMF buildings are higher when compared with the collapse probabilities of CSMF buildings. This is because CSMF building models are designed better to withstand earthquakes.

Tables 14 and 15 show the risk score calculated for 50 year period and 150 year period respectively using collapse risk, at high hazard locations. These tables are also color coded in a similar way as Table 12. In this table, the color varies from red color for the lowest value of risk score in the table to green color which is the highest value of risk score in the table. Low value of risk score indicates a higher collapse frequency in τ years and vice-versa. As we can see from the tables, CSMF frames have a lower collapse risk than the COMF frames. This is because CSMF frames are designed better to resist earthquakes through ductile detailing.

Tables 16 and 17 show the PMF_R values at high hazard locations for 50 year period and 150 year period respectively. These tables are color coded so the green color indicates that PMF_R is equal to 0 and yellow color indicates the negative and positive PMF_R values farthest from zero. A whole numbered PMF_R of 0, 1, 2 etc. would give a physical meaning to PMF_R in comparison of collapse probability and collapse risk. In this study, a PMF_R value varying ±0.25 from a whole numbered value of PMF_R is assumed to be acceptable.

Collapse probability of buildings given MCER level shaking(high hazard)																									
		High hazard location																							
Archetype	Model Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Average
1003	CSMF	0.10	0.00	0.04	0.11	0.11	0.59	0.54	0.29	0.01	0.19	0.14	0.04	0.03	0.15	0.00	0.01	0.61	0.09	0.23	0.04	0.00	0.05	0.17	0.15
1011	CSMF	0.22	0.01	0.10	0.24	0.24	0.77	0.73	0.49	0.05	0.36	0.29	0.12	0.10	0.30	0.00	0.02	0.79	0.20	0.41	0.11	0.01	0.12	0.34	0.26
5013	CSMF	0.15	0.00	0.06	0.15	0.16	0.67	0.62	0.37	0.02	0.26	0.20	0.07	0.05	0.20	0.00	0.01	0.69	0.13	0.30	0.06	0.00	0.07	0.24	0.20
5020	CSMF	0.09	0.00	0.03	0.09	0.10	0.56	0.50	0.27	0.01	0.17	0.13	0.04	0.03	0.13	0.00	0.00	0.58	0.07	0.21	0.03	0.00	0.04	0.16	0.14
1008	CSMF	0.07	0.00	0.02	0.08	0.08	0.51	0.46	0.23	0.01	0.14	0.10	0.03	0.02	0.11	0.00	0.00	0.53	0.06	0.18	0.03	0.00	0.03	0.13	0.12
1012	CSMF	0.10	0.00	0.04	0.11	0.11	0.59	0.53	0.29	0.01	0.19	0.14	0.04	0.03	0.15	0.00	0.01	0.61	0.08	0.23	0.04	0.00	0.05	0.17	0.15
5014	CSMF	0.11	0.00	0.04	0.11	0.12	0.60	0.55	0.30	0.02	0.20	0.15	0.05	0.04	0.16	0.00	0.01	0.63	0.09	0.24	0.04	0.00	0.05	0.18	0.16
5021	CSMF	0.04	0.00	0.01	0.05	0.05	0.42	0.37	0.16	0.00	0.10	0.07	0.02	0.01	0.07	0.00	0.00	0.44	0.04	0.12	0.02	0.00	0.02	0.09	0.09
6011	CSMF	0.84	0.21	0.69	0.85	0.86	0.99	0.99	0.96	0.53	0.92	0.89	0.72	0.67	0.89	0.13	0.41	0.99	0.82	0.94	0.71	0.22	0.72	0.91	0.73
6013	CSMF	0.78	0.15	0.60	0.79	0.79	0.99	0.98	0.93	0.44	0.88	0.84	0.63	0.58	0.84	0.09	0.32	0.99	0.75	0.90	0.62	0.16	0.64	0.87	0.68
6020	CSMF	0.69	0.10	0.49	0.71	0.71	0.98	0.97	0.89	0.34	0.82	0.76	0.53	0.48	0.77	0.05	0.23	0.98	0.66	0.85	0.52	0.10	0.54	0.80	0.61
6021	CSMF	0.31	0.01	0.16	0.33	0.33	0.85	0.81	0.60	0.08	0.47	0.39	0.18	0.15	0.40	0.00	0.04	0.86	0.28	0.52	0.17	0.01	0.19	0.44	0.33
1009	CSMF	0.02	0.00	0.01	0.02	0.02	0.30	0.25	0.10	0.00	0.05	0.03	0.01	0.00	0.04	0.00	0.00	0.32	0.02	0.07	0.01	0.00	0.01	0.04	0.06
1010	CSMF	0.01	0.00	0.00	0.01	0.01	0.16	0.13	0.04	0.00	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.17	0.00	0.02	0.00	0.00	0.00	0.02	0.03
9101	COMF	0.78	0.21	0.58	0.79	0.79	0.98	0.95	0.92	0.44	0.87	0.83	0.66	0.58	0.83	0.14	0.38	0.98	0.76	0.89	0.64	0.22	0.63	0.82	0.68
9103	COMF	0.95	0.51	0.87	0.95	0.95	1.00	1.00	0.99	0.79	0.97	0.96	0.89	0.87	0.96	0.40	0.70	1.00	0.94	0.98	0.88	0.53	0.89	0.97	0.87
9105	COMF	0.96	0.58	0.90	0.96	0.96	1.00	1.00	0.99	0.83	0.98	0.97	0.92	0.90	0.97	0.47	0.75	1.00	0.95	0.99	0.91	0.59	0.92	0.98	0.89
9107	COMF	0.94	0.51	0.87	0.95	0.95	1.00	1.00	0.99	0.79	0.97	0.96	0.89	0.87	0.96	0.40	0.70	1.00	0.93	0.98	0.88	0.52	0.89	0.97	0.87
9102	COMF	0.88	0.34	0.72	0.88	0.89	0.99	0.98	0.96	0.59	0.93	0.91	0.78	0.72	0.91	0.25	0.53	0.99	0.86	0.95	0.77	0.35	0.76	0.90	0.78
9104	COMF	0.96	0.58	0.91	0.96	0.97	1.00	1.00	0.99	0.84	0.98	0.97	0.92	0.90	0.98	0.47	0.76	1.00	0.96	0.99	0.91	0.59	0.92	0.98	0.89
9106	COMF	0.80	0.23	0.65	0.81	0.81	0.98	0.98	0.93	0.51	0.88	0.85	0.68	0.64	0.85	0.16	0.41	0.99	0.78	0.90	0.67	0.24	0.68	0.87	0.71
9108	COMF	0.84	0.28	0.70	0.85	0.85	0.99	0.99	0.95	0.57	0.91	0.88	0.73	0.69	0.88	0.20	0.46	0.99	0.82	0.93	0.72	0.29	0.74	0.90	0.75
9201	COMF	0.87	0.32	0.65	0.86	0.88	0.99	0.97	0.96	0.52	0.93	0.88	0.77	0.65	0.90	0.23	0.50	0.99	0.83	0.93	0.76	0.33	0.70	0.86	0.75
9203	COMF	0.86	0.32	0.74	0.87	0.87	0.99	0.99	0.96	0.62	0.93	0.90	0.77	0.73	0.90	0.23	0.51	0.99	0.85	0.94	0.76	0.33	0.77	0.92	0.77
9205	COMF	0.92	0.43	0.83	0.92	0.93	1.00	1.00	0.98	0.73	0.96	0.94	0.85	0.82	0.94	0.33	0.63	1.00	0.91	0.97	0.84	0.44	0.85	0.95	0.83
9207	COMF	0.89	0.37	0.78	0.90	0.90	0.99	0.99	0.97	0.67	0.94	0.92	0.81	0.77	0.92	0.27	0.56	1.00	0.88	0.96	0.80	0.38	0.81	0.94	0.80
9202	COMF	0.91	0.41	0.73	0.91	0.92	1.00	0.98	0.98	0.61	0.95	0.92	0.83	0.73	0.94	0.30	0.59	0.99	0.88	0.96	0.82	0.42	0.78	0.91	0.80
9204	COMF	0.85	0.29	0.72	0.85	0.86	0.99	0.99	0.95	0.59	0.92	0.89	0.74	0.71	0.89	0.21	0.48	0.99	0.83	0.93	0.73	0.30	0.75	0.91	0.75
9206	COMF	0.76	0.20	0.61	0.77	0.78	0.98	0.97	0.91	0.47	0.86	0.82	0.64	0.59	0.82	0.13	0.36	0.98	0.74	0.88	0.62	0.21	0.64	0.85	0.68
9208	COMF	0.89	0.36	0.78	0.89	0.90	0.99	0.99	0.97	0.66	0.94	0.92	0.80	0.77	0.92	0.27	0.56	0.99	0.87	0.95	0.79	0.37	0.81	0.93	0.80
	Average	0.59	0.22	0.48	0.59	0.60	0.83	0.81	0.71	0.39	0.66	0.62	0.50	0.47	0.63	0.16	0.33	0.84	0.57	0.68	0.50	0.22	0.50	0.64	0.54

Table 10 : Collapse probabilities conditioned on MCE_R S_{MT} shaking at high hazard locations

Score based on collapse probability																									
		High hazard locations																							
Archetype	Model Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Average
1003	CSMF	0.99	2.98	1.44	0.97	0.95	0.23	0.27	0.53	1.85	0.71	0.84	1.35	1.47	0.83	3.46	2.22	0.21	1.06	0.63	1.38	2.93	1.33	0.76	1.28
1011	CSMF	0.65	2.28	1.00	0.63	0.62	0.11	0.14	0.31	1.33	0.44	0.53	0.93	1.02	0.52	2.69	1.64	0.10	0.70	0.38	0.95	2.24	0.91	0.47	0.90
5013	CSMF	0.84	2.67	1.24	0.81	0.80	0.17	0.21	0.43	1.62	0.59	0.70	1.16	1.27	0.69	3.12	1.96	0.16	0.90	0.52	1.19	2.62	1.14	0.62	1.11
5020	CSMF	1.06	3.09	1.52	1.03	1.01	0.25	0.30	0.58	1.94	0.76	0.90	1.43	1.55	0.88	3.59	2.32	0.24	1.13	0.68	1.46	3.05	1.41	0.81	1.35
1008	CSMF	1.15	3.28	1.64	1.12	1.11	0.29	0.34	0.64	2.08	0.84	0.99	1.54	1.67	0.97	3.79	2.47	0.27	1.23	0.76	1.58	3.23	1.52	0.89	1.45
1012	CSMF	1.00	2.99	1.45	0.98	0.96	0.23	0.28	0.54	1.86	0.72	0.85	1.36	1.48	0.84	3.48	2.24	0.22	1.07	0.64	1.40	2.95	1.35	0.77	1.29
5014	CSMF	0.97	2.92	1.41	0.94	0.93	0.22	0.26	0.52	1.81	0.69	0.82	1.32	1.44	0.81	3.41	2.18	0.20	1.04	0.61	1.35	2.88	1.30	0.73	1.25
5021	CSMF	1.36	3.64	1.89	1.32	1.31	0.38	0.44	0.78	2.36	1.01	1.17	1.78	1.92	1.15	4.18	2.79	0.35	1.44	0.91	1.82	3.59	1.76	1.07	1.67
6011	CSMF	0.07	0.67	0.16	0.07	0.07	0.00	0.00	0.02	0.27	0.04	0.05	0.14	0.17	0.05	0.88	0.39	0.00	0.09	0.03	0.15	0.65	0.14	0.04	0.18
6013	CSMF	0.11	0.82	0.22	0.10	0.10	0.01	0.01	0.03	0.36	0.06	0.08	0.20	0.23	0.08	1.06	0.50	0.00	0.12	0.04	0.21	0.80	0.19	0.06	0.23
6020	CSMF	0.16	1.01	0.31	0.15	0.15	0.01	0.01	0.05	0.47	0.09	0.12	0.28	0.32	0.11	1.27	0.63	0.01	0.18	0.07	0.29	0.99	0.27	0.10	0.31
6021	CSMF	0.50	1.95	0.80	0.48	0.48	0.07	0.09	0.22	1.09	0.33	0.41	0.74	0.82	0.40	2.34	1.37	0.07	0.55	0.28	0.76	1.92	0.73	0.35	0.73
1009	CSMF	1.68	4.21	2.28	1.64	1.63	0.53	0.60	1.02	2.81	1.29	1.47	2.17	2.32	1.45	4.79	3.28	0.50	1.78	1.17	2.21	4.15	2.14	1.35	2.02
1010	CSMF	2.21	5.08	2.91	2.17	2.15	0.80	0.90	1.42	3.51	1.74	1.96	2.77	2.95	1.94	5.72	4.04	0.76	2.32	1.60	2.82	5.01	2.75	1.82	2.58
9101	COMF	0.11	0.67	0.24	0.10	0.10	0.01	0.02	0.04	0.36	0.06	0.08	0.18	0.24	0.08	0.85	0.42	0.01	0.12	0.05	0.19	0.65	0.20	0.09	0.21
9103	COMF	0.02	0.29	0.06	0.02	0.02	0.00	0.00	0.01	0.10	0.01	0.02	0.05	0.06	0.02	0.39	0.15	0.00	0.03	0.01	0.05	0.28	0.05	0.01	0.07
9105	COMF	0.02	0.24	0.04	0.02	0.02	0.00	0.00	0.00	0.08	0.01	0.01	0.04	0.05	0.01	0.33	0.12	0.00	0.02	0.01	0.04	0.23	0.04	0.01	0.06
9107	COMF	0.02	0.29	0.06	0.02	0.02	0.00	0.00	0.01	0.10	0.01	0.02	0.05	0.06	0.02	0.40	0.16	0.00	0.03	0.01	0.05	0.28	0.05	0.01	0.07
9102	COMF	0.06	0.47	0.14	0.05	0.05	0.00	0.01	0.02	0.23	0.03	0.04	0.11	0.14	0.04	0.61	0.27	0.00	0.07	0.02	0.11	0.45	0.12	0.05	0.13
9104	COMF	0.02	0.23	0.04	0.02	0.02	0.00	0.00	0.00	0.08	0.01	0.01	0.04	0.04	0.01	0.33	0.12	0.00	0.02	0.01	0.04	0.23	0.04	0.01	0.06
9106	COMF	0.10	0.63	0.19	0.09	0.09	0.01	0.01	0.03	0.29	0.05	0.07	0.17	0.19	0.07	0.80	0.39	0.01	0.11	0.04	0.18	0.62	0.16	0.06	0.19
9108	COMF	0.08	0.55	0.15	0.07	0.07	0.00	0.01	0.02	0.24	0.04	0.06	0.14	0.16	0.05	0.71	0.33	0.00	0.09	0.03	0.14	0.54	0.13	0.05	0.16
9201	COMF	0.06	0.49	0.18	0.06	0.06	0.00	0.01	0.02	0.28	0.03	0.06	0.12	0.18	0.04	0.64	0.30	0.01	0.08	0.03	0.12	0.48	0.15	0.06	0.15
9203	COMF	0.06	0.49	0.13	0.06	0.06	0.00	0.00	0.02	0.21	0.03	0.05	0.12	0.14	0.04	0.64	0.29	0.00	0.07	0.03	0.12	0.48	0.11	0.04	0.14
9205	COMF	0.04	0.36	0.08	0.03	0.03	0.00	0.00	0.01	0.14	0.02	0.03	0.07	0.09	0.02	0.48	0.20	0.00	0.04	0.01	0.08	0.35	0.07	0.02	0.10
9207	COMF	0.05	0.43	0.11	0.05	0.05	0.00	0.00	0.01	0.18	0.03	0.04	0.09	0.11	0.03	0.57	0.25	0.00	0.06	0.02	0.10	0.42	0.09	0.03	0.12
9202	COMF	0.04	0.39	0.13	0.04	0.04	0.00	0.01	0.01	0.22	0.02	0.04	0.08	0.14	0.03	0.52	0.23	0.00	0.05	0.02	0.08	0.38	0.11	0.04	0.11
9204	COMF	0.07	0.53	0.15	0.07	0.07	0.00	0.01	0.02	0.23	0.04	0.05	0.13	0.15	0.05	0.69	0.32	0.00	0.08	0.03	0.14	0.52	0.13	0.04	0.15
9206	COMF	0.12	0.70	0.22	0.11	0.11	0.01	0.01	0.04	0.33	0.07	0.09	0.20	0.23	0.09	0.88	0.44	0.01	0.13	0.05	0.20	0.68	0.19	0.07	0.22
9208	COMF	0.05	0.44	0.11	0.05	0.05	0.00	0.00	0.01	0.18	0.03	0.04	0.10	0.11	0.04	0.58	0.26	0.00	0.06	0.02	0.10	0.43	0.09	0.03	0.12
	Average	0.46	1.49	0.68	0.44	0.44	0.11	0.13	0.25	0.89	0.33	0.39	0.63	0.69	0.38	1.77	1.08	0.11	0.49	0.29	0.64	1.47	0.62	0.35	0.61

Table 11 : Score calculated using collapse probabilities at high hazard locations

Annual collapse risk to a building due to seismic hazard at a location																									
		Collapse Risk (High Hazard)																							
Archetype	Model Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Average
1003	CSMF	7E-05	3E-06	4E-05	6E-05	2E-04	6E-04	6E-04	2E-04	4E-04	8E-05	7E-05	1E-05	1E-05	1E-04	2E-06	1E-05	5E-04	1E-04	2E-04	7E-05	9E-06	2E-05	6E-06	1E-04
1011	CSMF	6E-04	5E-05	4E-04	1E-03	2E-03	3E-03	3E-03	1E-03	3E-03	1E-03	1E-03	4E-04	4E-04	6E-04	4E-05	1E-04	1E-03	6E-04	7E-04	4E-04	8E-05	5E-04	2E-04	1E-03
5013	CSMF	1E-03	9E-05	6E-04	2E-03	4E-03	4E-03	4E-03	2E-03	5E-03	2E-03	2E-03	8E-04	8E-04	8E-04	7E-05	2E-04	1E-03	8E-04	8E-04	5E-04	1E-04	1E-03	3E-04	1E-03
5020	CSMF	2E-03	2E-04	1E-03	5E-03	7E-03	5E-03	6E-03	3E-03	8E-03	4E-03	5E-03	2E-03	2E-03	1E-03	2E-04	5E-04	2E-03	1E-03	1E-03	8E-04	2E-04	2E-03	8E-04	3E-03
1008	CSMF	6E-05	2E-06	3E-05	4E-05	1E-04	4E-04	5E-04	2E-04	3E-04	6E-05	5E-05	9E-06	7E-06	1E-04	1E-06	8E-06	4E-04	8E-05	2E-04	6E-05	7E-06	1E-05	3E-06	1E-04
1012	CSMF	3E-04	2E-05	2E-04	6E-04	1E-03	2E-03	2E-03	8E-04	2E-03	6E-04	6E-04	2E-04	1E-04	4E-04	2E-05	7E-05	1E-03	3E-04	5E-04	2E-04	4E-05	2E-04	6E-05	6E-04
5014	CSMF	8E-04	7E-05	5E-04	2E-03	3E-03	3E-03	4E-03	2E-03	4E-03	2E-03	2E-03	6E-04	6E-04	7E-04	5E-05	2E-04	1E-03	7E-04	8E-04	4E-04	1E-04	7E-04	2E-04	1E-03
5021	CSMF	1E-03	1E-04	7E-04	3E-03	5E-03	4E-03	5E-03	2E-03	6E-03	3E-03	3E-03	1E-03	1E-03	1E-03	1E-04	3E-04	2E-03	9E-04	9E-04	6E-04	2E-04	1E-03	5E-04	2E-03
6011	CSMF	4E-03	6E-04	2E-03	1E-02	1E-02	1E-02	1E-02	6E-03	2E-02	1E-02	1E-02	5E-03	6E-03	2E-03	4E-04	1E-03	2E-03	2E-03	2E-03	1E-03	5E-04	6E-03	2E-03	6E-03
6013	CSMF	6E-03	1E-03	3E-03	2E-02	2E-02	1E-02	2E-02	9E-03	2E-02	1E-02	2E-02	9E-03	9E-03	3E-03	7E-04	1E-03	3E-03	2E-03	2E-03	2E-03	8E-04	9E-03	4E-03	8E-03
6020	CSMF	1E-02	2E-03	4E-03	3E-02	3E-02	2E-02	2E-02	1E-02	3E-02	2E-02	3E-02	2E-02	2E-02	4E-03	1E-03	2E-03	3E-03	3E-03	2E-03	2E-03	1E-03	2E-02	7E-03	1E-02
6021	CSMF	5E-03	7E-04	2E-03	1E-02	2E-02	1E-02	1E-02	7E-03	2E-02	1E-02	1E-02	6E-03	7E-03	2E-03	5E-04	1E-03	2E-03	2E-03	2E-03	1E-03	6E-04	7E-03	3E-03	6E-03
1009	CSMF	5E-05	2E-06	2E-05	4E-05	1E-04	4E-04	5E-04	1E-04	3E-04	5E-05	5E-05	7E-06	6E-06	1E-04	1E-06	7E-06	4E-04	7E-05	2E-04	5E-05	7E-06	1E-05	3E-06	1E-04
1010	CSMF	3E-05	7E-07	1E-05	1E-05	6E-05	2E-04	3E-04	8E-05	1E-04	2E-05	2E-05	3E-06	2E-06	6E-05	4E-07	3E-06	2E-04	4E-05	1E-04	3E-05	4E-06	3E-06	9E-07	6E-05
9101	COMF	5E-04	4E-05	3E-04	1E-03	2E-03	2E-03	3E-03	1E-03	2E-03	1E-03	1E-03	3E-04	3E-04	5E-04	3E-05	1E-04	1E-03	4E-04	6E-04	3E-04	6E-05	4E-04	1E-04	8E-04
9103	COMF	4E-03	6E-04	2E-03	1E-02	1E-02	1E-02	1E-02	6E-03	2E-02	1E-02	1E-02	5E-03	6E-03	2E-03	4E-04	1E-03	2E-03	2E-03	1E-03	1E-03	5E-04	6E-03	2E-03	6E-03
9105	COMF	1E-02	2E-03	5E-03	3E-02	3E-02	2E-02	3E-02	1E-02	4E-02	3E-02	4E-02	2E-02	2E-02	5E-03	2E-03	2E-03	3E-03	3E-03	2E-03	2E-03	2E-03	2E-02	8E-03	1E-02
9107	COMF	2E-02	4E-03	7E-03	4E-02	4E-02	3E-02	4E-02	2E-02	5E-02	4E-02	5E-02	3E-02	3E-02	6E-03	2E-03	3E-03	4E-03	4E-03	3E-03	3E-03	2E-03	3E-02	1E-02	2E-02
9102	COMF	8E-04	8E-05	5E-04	2E-03	3E-03	3E-03	4E-03	2E-03	4E-03	2E-03	2E-03	6E-04	6E-04	7E-04	6E-05	2E-04	1E-03	6E-04	7E-04	4E-04	1E-04	8E-04	3E-04	1E-03
9104	COMF	5E-03	7E-04	2E-03	1E-02	2E-02	1E-02	1E-02	7E-03	2E-02	1E-02	1E-02	7E-03	7E-03	2E-03	5E-04	1E-03	2E-03	2E-03	2E-03	1E-03	6E-04	7E-03	3E-03	6E-03
9106	COMF	6E-03	8E-04	3E-03	1E-02	2E-02	1E-02	1E-02	8E-03	2E-02	1E-02	2E-02	8E-03	8E-03	3E-03	6E-04	1E-03	3E-03	2E-03	2E-03	1E-03	7E-04	8E-03	3E-03	7E-03
9108	COMF	1E-02	2E-03	5E-03	3E-02	3E-02	2E-02	2E-02	1E-02	4E-02	2E-02	3E-02	2E-02	2E-02	4E-03	1E-03	2E-03	3E-03	3E-03	2E-03	2E-03	1E-03	2E-02	7E-03	1E-02
9201	COMF	7E-04	6E-05	4E-04	1E-03	2E-03	3E-03	3E-03	1E-03	3E-03	1E-03	1E-03	5E-04	5E-04	6E-04	4E-05	2E-04	1E-03	5E-04	6E-04	4E-04	8E-05	6E-04	2E-04	1E-03
9203	COMF	2E-03	3E-04	1E-03	6E-03	7E-03	6E-03	7E-03	4E-03	9E-03	5E-03	6E-03	2E-03	3E-03	1E-03	2E-04	6E-04	2E-03	1E-03	1E-03	8E-04	3E-04	3E-03	1E-03	3E-03
9205	COMF	8E-03	1E-03	4E-03	2E-02	2E-02	2E-02	2E-02	1E-02	3E-02	2E-02	3E-02	1E-02	1E-02	3E-03	1E-03	2E-03	3E-03	2E-03	2E-03	2E-03	1E-03	1E-02	5E-03	1E-02
9207	COMF	1E-02	2E-03	5E-03	3E-02	3E-02	2E-02	3E-02	1E-02	4E-02	3E-02	4E-02	2E-02	2E-02	5E-03	2E-03	2E-03	3E-03	3E-03	2E-03	2E-03	2E-03	2E-02	8E-03	1E-02
9202	COMF	9E-04	9E-05	5E-04	2E-03	3E-03	3E-03	4E-03	2E-03	4E-03	2E-03	2E-03	7E-04	7E-04	7E-04	6E-05	2E-04	1E-03	7E-04	7E-04	4E-04	1E-04	9E-04	3E-04	1E-03
9204	COMF	2E-03	2E-04	1E-03	5E-03	7E-03	6E-03	7E-03	3E-03	9E-03	5E-03	6E-03	2E-03	2E-03	1E-03	2E-04	5E-04	2E-03	1E-03	1E-03	8E-04	3E-04	2E-03	9E-04	3E-03
9206	COMF	4E-03	6E-04	2E-03	1E-02	1E-02	1E-02	1E-02	6E-03	2E-02	1E-02	1E-02	6E-03	6E-03	2E-03	5E-04	1E-03	2E-03	2E-03	2E-03	1E-03	6E-04	6E-03	2E-03	6E-03
9208	COMF	1E-02	2E-03	5E-03	3E-02	3E-02	2E-02	3E-02	1E-02	4E-02	3E-02	4E-02	2E-02	2E-02	5E-03	2E-03	2E-03	3E-03	3E-03	2E-03	2E-03	2E-03	2E-02	8E-03	1E-02
	Average	4E-03	7E-04	2E-03	1E-02	1E-02	1E-02	1E-02	6E-03	2E-02	1E-02	1E-02	6E-03	7E-03	2E-03	5E-04	9E-04	2E-03	1E-03	1E-03	1E-03	6E-04	7E-03	3E-03	6E-03

Table 12 : Annual collapse risk calculated using hazard curves at high hazard locations

Risk score based on collapse risk for 50 year period																									
		High hazard locations																							
Archetype	Model Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Average
1003	CSMF	2.44	3.81	2.75	2.49	2.01	1.55	1.49	1.97	1.71	2.38	2.43	3.16	3.27	2.16	4.05	3.28	1.64	2.31	1.99	2.46	3.33	3.03	3.56	2.58
1011	CSMF	1.49	2.58	1.76	1.17	0.96	0.89	0.81	1.16	0.82	1.22	1.20	1.70	1.73	1.51	2.73	2.14	1.20	1.56	1.48	1.75	2.40	1.59	2.08	1.56
5013	CSMF	1.29	2.33	1.56	0.92	0.76	0.75	0.67	1.00	0.63	0.99	0.94	1.41	1.42	1.38	2.47	1.91	1.13	1.41	1.38	1.61	2.20	1.32	1.80	1.36
5020	CSMF	1.01	1.98	1.29	0.60	0.49	0.56	0.49	0.78	0.38	0.67	0.60	1.03	1.02	1.20	2.12	1.61	1.04	1.24	1.26	1.42	1.92	0.96	1.42	1.09
1008	CSMF	2.56	3.98	2.88	2.68	2.15	1.65	1.59	2.09	1.82	2.53	2.58	3.36	3.47	2.25	4.23	3.42	1.71	2.41	2.07	2.56	3.44	3.23	3.76	2.71
1012	CSMF	1.77	2.93	2.04	1.53	1.25	1.07	0.99	1.38	1.08	1.56	1.55	2.11	2.16	1.69	3.09	2.47	1.31	1.76	1.62	1.95	2.68	1.98	2.49	1.85
5014	CSMF	1.38	2.44	1.64	1.03	0.84	0.81	0.73	1.07	0.72	1.09	1.05	1.54	1.56	1.43	2.58	2.01	1.16	1.48	1.42	1.67	2.29	1.43	1.92	1.45
5021	CSMF	1.17	2.17	1.44	0.78	0.64	0.67	0.59	0.90	0.52	0.85	0.79	1.25	1.25	1.30	2.31	1.78	1.09	1.33	1.33	1.52	2.08	1.16	1.63	1.24
6011	CSMF	0.67	1.54	0.98	0.24	0.17	0.30	0.24	0.51	0.08	0.30	0.20	0.57	0.55	0.97	1.68	1.28	0.93	1.05	1.11	1.21	1.57	0.54	0.96	0.77
6013	CSMF	0.50	1.32	0.83	0.08	0.02	0.16	0.11	0.37	-0.06	0.13	0.02	0.36	0.33	0.86	1.47	1.14	0.87	0.96	1.05	1.12	1.40	0.35	0.75	0.61
6020	CSMF	0.30	1.04	0.65	-0.11	-0.16	-0.02	-0.07	0.19	-0.24	-0.08	-0.20	0.09	0.05	0.69	1.21	0.97	0.79	0.86	0.96	1.01	1.19	0.10	0.48	0.42
6021	CSMF	0.62	1.47	0.94	0.19	0.12	0.26	0.21	0.47	0.03	0.25	0.15	0.51	0.48	0.94	1.62	1.24	0.91	1.02	1.09	1.19	1.52	0.48	0.90	0.72
1009	CSMF	2.60	4.04	2.93	2.75	2.20	1.69	1.63	2.13	1.86	2.59	2.64	3.44	3.55	2.29	4.30	3.47	1.74	2.46	2.10	2.59	3.48	3.31	3.84	2.77
1010	CSMF	2.88	4.44	3.25	3.20	2.55	1.92	1.87	2.42	2.13	2.94	2.99	3.90	4.02	2.52	4.74	3.78	1.92	2.71	2.28	2.82	3.73	3.77	4.33	3.09
9101	COMF	1.58	2.67	1.85	1.26	1.06	0.97	0.89	1.25	0.91	1.32	1.28	1.78	1.81	1.59	2.82	2.24	1.26	1.65	1.55	1.84	2.49	1.68	2.17	1.65
9103	COMF	0.67	1.52	0.99	0.25	0.18	0.31	0.25	0.52	0.09	0.31	0.20	0.56	0.53	0.98	1.67	1.30	0.94	1.07	1.13	1.23	1.57	0.54	0.95	0.77
9105	COMF	0.23	0.93	0.60	-0.17	-0.21	-0.09	-0.13	0.13	-0.29	-0.14	-0.27	0.00	-0.05	0.63	1.11	0.92	0.76	0.83	0.93	0.98	1.12	0.01	0.39	0.36
9107	COMF	0.08	0.74	0.47	-0.29	-0.33	-0.23	-0.26	-0.01	-0.41	-0.28	-0.42	-0.18	-0.23	0.50	0.92	0.80	0.68	0.75	0.86	0.89	0.96	-0.17	0.20	0.22
9102	COMF	1.37	2.40	1.64	1.01	0.84	0.82	0.74	1.08	0.72	1.07	1.02	1.49	1.50	1.45	2.55	2.00	1.18	1.50	1.45	1.69	2.28	1.40	1.88	1.44
9104	COMF	0.60	1.43	0.93	0.18	0.12	0.25	0.19	0.46	0.03	0.23	0.13	0.47	0.44	0.93	1.58	1.23	0.92	1.03	1.10	1.19	1.50	0.46	0.86	0.71
9106	COMF	0.56	1.37	0.89	0.14	0.08	0.21	0.16	0.42	-0.01	0.19	0.08	0.42	0.38	0.90	1.53	1.20	0.90	1.01	1.08	1.17	1.46	0.40	0.81	0.67
9108	COMF	0.28	1.00	0.64	-0.12	-0.17	-0.04	-0.08	0.17	-0.25	-0.09	-0.22	0.06	0.02	0.67	1.17	0.96	0.78	0.86	0.95	1.01	1.17	0.07	0.45	0.40
9201	COMF	1.47	2.53	1.74	1.13	0.94	0.89	0.81	1.16	0.81	1.19	1.14	1.63	1.64	1.52	2.67	2.11	1.22	1.57	1.50	1.76	2.38	1.53	2.01	1.54
9203	COMF	0.94	1.86	1.23	0.53	0.43	0.52	0.45	0.74	0.32	0.59	0.51	0.91	0.89	1.17	2.01	1.55	1.03	1.22	1.24	1.40	1.85	0.86	1.30	1.02
9205	COMF	0.39	1.15	0.74	-0.02	-0.07	0.06	0.02	0.27	-0.15	0.02	-0.10	0.20	0.16	0.77	1.31	1.05	0.83	0.92	1.01	1.07	1.28	0.20	0.59	0.51
9207	COMF	0.23	0.94	0.60	-0.16	-0.21	-0.09	-0.13	0.13	-0.29	-0.14	-0.27	0.00	-0.05	0.63	1.11	0.92	0.76	0.83	0.93	0.98	1.12	0.01	0.39	0.36
9202	COMF	1.35	2.37	1.62	0.98	0.82	0.81	0.73	1.06	0.69	1.04	0.99	1.46	1.46	1.44	2.51	1.97	1.17	1.48	1.43	1.67	2.25	1.37	1.84	1.41
9204	COMF	0.98	1.91	1.27	0.56	0.46	0.54	0.47	0.76	0.36	0.63	0.55	0.96	0.94	1.19	2.05	1.59	1.04	1.24	1.26	1.42	1.88	0.90	1.35	1.06
9206	COMF	0.65	1.49	0.97	0.23	0.16	0.29	0.23	0.50	0.07	0.28	0.18	0.53	0.50	0.97	1.64	1.28	0.93	1.05	1.12	1.22	1.55	0.51	0.92	0.75
9208	COMF	0.24	0.94	0.61	-0.16	-0.20	-0.08	-0.12	0.13	-0.28	-0.14	-0.26	0.01	-0.04	0.64	1.12	0.93	0.76	0.84	0.93	0.98	1.12	0.02	0.39	0.36
	Average	1.08	2.04	1.39	0.76	0.60	0.58	0.52	0.84	0.46	0.78	0.72	1.16	1.16	1.24	2.21	1.75	1.09	1.35	1.32	1.51	1.97	1.10	1.55	1.18

Table 13 : Risk score calculated for 50 year period using collapse risk, at high hazard locations

Risk score based on collapse risk for 150 year period																									
		High hazard locations																							
Archetype	Model Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Average
1003	CSMF	1.96	3.33	2.27	2.01	1.53	1.08	1.01	1.49	1.23	1.91	1.95	2.69	2.79	1.68	3.57	2.80	1.16	1.83	1.52	1.99	2.85	2.55	3.08	2.10
1011	CSMF	1.02	2.10	1.28	0.69	0.48	0.41	0.33	0.68	0.35	0.75	0.72	1.22	1.25	1.03	2.25	1.66	0.72	1.08	1.00	1.27	1.93	1.11	1.61	1.08
5013	CSMF	0.81	1.85	1.08	0.44	0.28	0.28	0.20	0.52	0.16	0.51	0.46	0.94	0.95	0.90	1.99	1.43	0.65	0.94	0.91	1.13	1.72	0.84	1.32	0.88
5020	CSMF	0.54	1.50	0.82	0.13	0.01	0.09	0.01	0.31	-0.10	0.20	0.12	0.56	0.55	0.73	1.64	1.14	0.56	0.76	0.78	0.95	1.44	0.48	0.95	0.62
1008	CSMF	2.08	3.50	2.41	2.20	1.67	1.17	1.11	1.61	1.34	2.05	2.11	2.88	2.99	1.77	3.75	2.94	1.23	1.94	1.59	2.08	2.96	2.75	3.28	2.24
1012	CSMF	1.29	2.45	1.56	1.05	0.78	0.60	0.51	0.90	0.60	1.08	1.08	1.63	1.68	1.21	2.62	1.99	0.83	1.29	1.14	1.47	2.20	1.51	2.01	1.37
5014	CSMF	0.90	1.96	1.17	0.55	0.37	0.33	0.25	0.59	0.24	0.61	0.57	1.06	1.08	0.96	2.10	1.53	0.68	1.00	0.95	1.19	1.81	0.96	1.45	0.97
5021	CSMF	0.69	1.70	0.96	0.30	0.16	0.19	0.12	0.43	0.05	0.37	0.31	0.77	0.77	0.83	1.84	1.30	0.61	0.86	0.85	1.05	1.60	0.68	1.16	0.76
6011	CSMF	0.19	1.06	0.50	-0.24	-0.31	-0.18	-0.23	0.03	-0.40	-0.18	-0.28	0.10	0.07	0.50	1.20	0.80	0.45	0.57	0.63	0.74	1.09	0.06	0.49	0.29
6013	CSMF	0.03	0.84	0.36	-0.40	-0.46	-0.31	-0.36	-0.11	-0.54	-0.35	-0.46	-0.12	-0.15	0.38	0.99	0.66	0.40	0.49	0.57	0.64	0.93	-0.13	0.27	0.14
6020	CSMF	-0.18	0.56	0.18	-0.59	-0.64	-0.50	-0.54	-0.29	-0.71	-0.56	-0.68	-0.39	-0.43	0.21	0.73	0.49	0.31	0.38	0.48	0.53	0.71	-0.38	0.00	-0.06
6021	CSMF	0.14	1.00	0.46	-0.29	-0.35	-0.21	-0.27	-0.01	-0.44	-0.23	-0.33	0.03	0.00	0.46	1.14	0.76	0.44	0.54	0.62	0.71	1.04	0.01	0.42	0.25
1009	CSMF	2.12	3.56	2.46	2.27	1.73	1.21	1.15	1.66	1.38	2.11	2.17	2.96	3.07	1.81	3.83	2.99	1.26	1.98	1.62	2.12	3.00	2.83	3.36	2.29
1010	CSMF	2.41	3.96	2.77	2.72	2.07	1.45	1.40	1.95	1.65	2.46	2.52	3.42	3.54	2.04	4.26	3.31	1.44	2.23	1.80	2.34	3.26	3.29	3.85	2.61
9101	COMF	1.11	2.19	1.38	0.79	0.58	0.49	0.41	0.77	0.44	0.84	0.81	1.31	1.33	1.11	2.34	1.76	0.79	1.17	1.08	1.36	2.02	1.20	1.69	1.17
9103	COMF	0.20	1.05	0.51	-0.23	-0.30	-0.17	-0.23	0.04	-0.39	-0.17	-0.27	0.09	0.06	0.51	1.19	0.82	0.46	0.59	0.65	0.76	1.10	0.06	0.48	0.30
9105	COMF	-0.25	0.46	0.12	-0.64	-0.69	-0.57	-0.60	-0.35	-0.76	-0.62	-0.75	-0.48	-0.52	0.15	0.63	0.44	0.28	0.35	0.45	0.50	0.64	-0.47	-0.09	-0.12
9107	COMF	-0.40	0.26	-0.01	-0.77	-0.81	-0.71	-0.74	-0.49	-0.89	-0.76	-0.90	-0.66	-0.71	0.02	0.45	0.33	0.20	0.27	0.38	0.42	0.48	-0.65	-0.28	-0.26
9102	COMF	0.89	1.92	1.17	0.53	0.37	0.35	0.27	0.60	0.24	0.59	0.54	1.01	1.02	0.97	2.07	1.52	0.70	1.02	0.97	1.21	1.80	0.92	1.40	0.96
9104	COMF	0.13	0.95	0.45	-0.30	-0.36	-0.23	-0.28	-0.02	-0.45	-0.24	-0.35	0.00	-0.03	0.46	1.11	0.76	0.44	0.55	0.62	0.71	1.03	-0.02	0.39	0.23
9106	COMF	0.08	0.90	0.41	-0.34	-0.40	-0.27	-0.32	-0.06	-0.49	-0.29	-0.40	-0.06	-0.09	0.42	1.05	0.72	0.42	0.53	0.60	0.69	0.98	-0.07	0.33	0.19
9108	COMF	-0.20	0.52	0.17	-0.60	-0.64	-0.52	-0.56	-0.31	-0.72	-0.57	-0.70	-0.42	-0.46	0.20	0.69	0.48	0.31	0.38	0.48	0.53	0.69	-0.41	-0.03	-0.07
9201	COMF	0.99	2.05	1.26	0.65	0.47	0.42	0.34	0.68	0.33	0.71	0.67	1.15	1.16	1.04	2.20	1.63	0.74	1.09	1.02	1.28	1.90	1.05	1.53	1.06
9203	COMF	0.46	1.39	0.76	0.05	-0.05	0.04	-0.03	0.26	-0.15	0.12	0.03	0.44	0.42	0.69	1.53	1.07	0.55	0.74	0.77	0.92	1.37	0.38	0.83	0.55
9205	COMF	-0.09	0.67	0.26	-0.50	-0.55	-0.42	-0.46	-0.21	-0.63	-0.46	-0.58	-0.28	-0.32	0.29	0.84	0.58	0.36	0.44	0.53	0.59	0.81	-0.27	0.11	0.03
9207	COMF	-0.25	0.46	0.12	-0.64	-0.69	-0.57	-0.60	-0.35	-0.76	-0.62	-0.75	-0.48	-0.52	0.15	0.63	0.44	0.28	0.35	0.45	0.50	0.64	-0.47	-0.09	-0.12
9202	COMF	0.87	1.89	1.14	0.50	0.34	0.33	0.25	0.58	0.22	0.57	0.51	0.98	0.98	0.96	2.04	1.50	0.69	1.00	0.96	1.19	1.78	0.89	1.37	0.94
9204	COMF	0.50	1.43	0.79	0.09	-0.02	0.07	0.00	0.29	-0.12	0.15	0.07	0.48	0.47	0.72	1.57	1.11	0.56	0.76	0.78	0.94	1.40	0.43	0.87	0.58
9206	COMF	0.17	1.01	0.49	-0.25	-0.32	-0.19	-0.25	0.02	-0.41	-0.20	-0.30	0.06	0.03	0.49	1.16	0.80	0.45	0.58	0.64	0.74	1.07	0.03	0.45	0.27
9208	COMF	-0.24	0.47	0.13	-0.64	-0.68	-0.56	-0.60	-0.35	-0.76	-0.61	-0.74	-0.47	-0.51	0.16	0.64	0.45	0.29	0.36	0.46	0.51	0.65	-0.46	-0.08	-0.11
	Average	0.60	1.57	0.91	0.29	0.12	0.10	0.04	0.36	-0.02	0.31	0.24	0.68	0.68	0.76	1.74	1.27	0.61	0.87	0.84	1.04	1.50	0.62	1.07	0.70

Table 14 : Risk score calculated for 150 year period using collapse risk, at high hazard locations

PMFR																									
		High Hazard Locations																							
Archetype	Model Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Average
1003	CSMF	1.44	0.83	1.31	1.53	1.05	1.33	1.22	1.44	-0.14	1.67	1.59	1.81	1.80	1.33	0.59	1.06	1.42	1.25	1.36	1.08	0.40	1.70	2.80	1.30
1011	CSMF	0.84	0.30	0.76	0.54	0.34	0.78	0.67	0.84	-0.51	0.79	0.66	0.77	0.71	0.98	0.03	0.50	1.10	0.85	1.10	0.80	0.17	0.68	1.61	0.67
5013	CSMF	0.45	-0.34	0.32	0.11	-0.04	0.58	0.47	0.57	-0.98	0.40	0.24	0.25	0.16	0.69	-0.66	-0.05	0.97	0.52	0.87	0.42	-0.43	0.17	1.17	0.25
5020	CSMF	-0.04	-1.11	-0.22	-0.42	-0.53	0.31	0.19	0.21	-1.56	-0.09	-0.30	-0.39	-0.52	0.32	-1.47	-0.70	0.80	0.11	0.58	-0.04	-1.13	-0.45	0.61	-0.25
1008	CSMF	1.40	0.70	1.24	1.55	1.04	1.36	1.25	1.44	-0.26	1.69	1.60	1.82	1.80	1.28	0.44	0.94	1.43	1.18	1.31	0.98	0.21	1.70	2.87	1.26
1012	CSMF	0.77	-0.07	0.58	0.55	0.29	0.84	0.72	0.84	-0.78	0.83	0.70	0.74	0.68	0.85	-0.39	0.23	1.09	0.69	0.98	0.55	-0.27	0.64	1.72	0.56
5014	CSMF	0.41	-0.49	0.24	0.09	-0.08	0.59	0.47	0.55	-1.09	0.40	0.23	0.22	0.12	0.63	-0.83	-0.17	0.95	0.44	0.81	0.32	-0.59	0.13	1.19	0.20
5021	CSMF	-0.19	-1.47	-0.45	-0.54	-0.67	0.29	0.16	0.12	-1.84	-0.16	-0.38	-0.54	-0.68	0.15	-1.87	-1.01	0.73	-0.10	0.41	-0.30	-1.51	-0.60	0.57	-0.43
6011	CSMF	0.59	0.87	0.81	0.17	0.10	0.30	0.24	0.49	-0.20	0.26	0.15	0.43	0.37	0.92	0.80	0.89	0.93	0.96	1.08	1.06	0.92	0.40	0.92	0.59
6013	CSMF	0.39	0.50	0.61	-0.03	-0.08	0.16	0.11	0.34	-0.42	0.07	-0.06	0.16	0.09	0.78	0.42	0.64	0.87	0.84	1.00	0.91	0.60	0.15	0.69	0.38
6020	CSMF	0.14	0.03	0.35	-0.27	-0.31	-0.03	-0.08	0.14	-0.71	-0.17	-0.32	-0.18	-0.27	0.58	-0.07	0.33	0.78	0.68	0.89	0.72	0.20	-0.17	0.38	0.12
6021	CSMF	0.12	-0.48	0.13	-0.30	-0.35	0.19	0.11	0.24	-1.06	-0.08	-0.26	-0.23	-0.34	0.54	-0.72	-0.13	0.85	0.47	0.81	0.42	-0.39	-0.25	0.55	-0.01
1009	CSMF	0.92	-0.17	0.65	1.11	0.58	1.16	1.02	1.11	-0.95	1.30	1.17	1.27	1.23	0.84	-0.49	0.19	1.24	0.68	0.92	0.39	-0.67	1.16	2.49	0.75
1010	CSMF	0.67	-0.64	0.35	1.03	0.40	1.12	0.98	1.00	-1.38	1.19	1.03	1.12	1.06	0.58	-0.98	-0.25	1.16	0.38	0.67	0.00	-1.28	1.03	2.51	0.51
9101	COMF	1.48	2.00	1.61	1.16	0.96	0.96	0.87	1.21	0.56	1.26	1.20	1.60	1.57	1.51	1.97	1.82	1.25	1.53	1.50	1.65	1.84	1.48	2.08	1.44
9103	COMF	0.65	1.23	0.93	0.23	0.16	0.31	0.25	0.51	-0.01	0.30	0.19	0.51	0.47	0.97	1.28	1.14	0.94	1.04	1.12	1.18	1.30	0.49	0.94	0.70
9105	COMF	0.21	0.69	0.56	-0.18	-0.22	-0.09	-0.13	0.12	-0.37	-0.15	-0.28	-0.04	-0.09	0.62	0.78	0.80	0.76	0.81	0.93	0.94	0.88	-0.03	0.38	0.30
9107	COMF	0.06	0.44	0.41	-0.31	-0.36	-0.23	-0.27	-0.02	-0.51	-0.30	-0.44	-0.23	-0.30	0.48	0.53	0.65	0.68	0.72	0.85	0.84	0.68	-0.22	0.19	0.14
9102	COMF	1.31	1.93	1.50	0.95	0.79	0.82	0.74	1.06	0.49	1.04	0.98	1.38	1.35	1.41	1.94	1.72	1.18	1.43	1.42	1.57	1.82	1.28	1.83	1.30
9104	COMF	0.59	1.20	0.89	0.17	0.10	0.25	0.19	0.45	-0.05	0.23	0.12	0.44	0.40	0.92	1.26	1.11	0.92	1.01	1.09	1.15	1.28	0.42	0.86	0.65
9106	COMF	0.46	0.74	0.70	0.05	-0.01	0.20	0.15	0.39	-0.30	0.14	0.01	0.25	0.19	0.83	0.72	0.80	0.89	0.90	1.03	0.99	0.84	0.24	0.75	0.48
9108	COMF	0.20	0.45	0.49	-0.20	-0.24	-0.05	-0.09	0.15	-0.49	-0.14	-0.28	-0.08	-0.14	0.62	0.46	0.63	0.78	0.77	0.92	0.86	0.63	-0.06	0.40	0.24
9201	COMF	1.41	2.03	1.56	1.06	0.89	0.89	0.80	1.14	0.52	1.15	1.09	1.51	1.45	1.47	2.03	1.81	1.21	1.49	1.47	1.64	1.90	1.38	1.95	1.38
9203	COMF	0.88	1.37	1.10	0.47	0.37	0.51	0.44	0.72	0.12	0.56	0.46	0.80	0.76	1.12	1.36	1.26	1.03	1.15	1.22	1.28	1.36	0.75	1.27	0.88
9205	COMF	0.35	0.79	0.66	-0.06	-0.10	0.06	0.01	0.26	-0.29	0.00	-0.13	0.13	0.08	0.74	0.83	0.85	0.83	0.87	0.99	0.99	0.93	0.13	0.57	0.41
9207	COMF	0.18	0.50	0.49	-0.21	-0.25	-0.09	-0.13	0.11	-0.46	-0.17	-0.30	-0.09	-0.16	0.60	0.54	0.67	0.76	0.77	0.91	0.88	0.70	-0.08	0.36	0.24
9202	COMF	1.31	1.98	1.48	0.94	0.78	0.81	0.72	1.05	0.48	1.02	0.95	1.37	1.33	1.41	2.00	1.74	1.17	1.43	1.42	1.58	1.88	1.26	1.80	1.30
9204	COMF	0.91	1.38	1.12	0.50	0.39	0.54	0.47	0.74	0.13	0.59	0.50	0.83	0.79	1.14	1.36	1.27	1.04	1.16	1.23	1.28	1.36	0.78	1.31	0.90
9206	COMF	0.53	0.79	0.75	0.11	0.05	0.28	0.22	0.46	-0.26	0.22	0.09	0.34	0.28	0.88	0.76	0.83	0.92	0.92	1.06	1.01	0.87	0.32	0.85	0.53
9208	COMF	0.18	0.50	0.50	-0.21	-0.25	-0.09	-0.12	0.12	-0.46	-0.16	-0.30	-0.09	-0.15	0.60	0.54	0.67	0.76	0.78	0.91	0.88	0.70	-0.08	0.37	0.24
	Average	0.62	0.55	0.71	0.32	0.16	0.47	0.39	0.59	-0.43	0.46	0.33	0.53	0.47	0.86	0.44	0.68	0.98	0.86	1.03	0.87	0.51	0.48	1.20	0.57

Table 15 : PMF_R values (τ = 50 years) at high hazard locations

PMFR																									
		High Hazard Locations																							
Archetype	Model Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Average
1003	CSMF	0.96	0.36	0.83	1.05	0.58	0.85	0.74	0.96	-0.62	1.19	1.11	1.33	1.32	0.85	0.11	0.58	0.95	0.77	0.88	0.60	-0.08	1.22	2.32	0.82
1011	CSMF	0.37	-0.17	0.28	0.06	-0.13	0.30	0.19	0.37	-0.98	0.31	0.18	0.30	0.23	0.51	-0.44	0.03	0.62	0.38	0.62	0.32	-0.31	0.20	1.14	0.19
5013	CSMF	-0.02	-0.82	-0.16	-0.37	-0.52	0.10	-0.01	0.09	-1.46	-0.08	-0.24	-0.22	-0.32	0.21	-1.13	-0.53	0.49	0.04	0.39	-0.06	-0.90	-0.30	0.70	-0.22
5020	CSMF	-0.52	-1.59	-0.70	-0.90	-1.00	-0.17	-0.29	-0.27	-2.03	-0.57	-0.77	-0.87	-1.00	-0.16	-1.95	-1.18	0.32	-0.37	0.10	-0.51	-1.60	-0.92	0.14	-0.73
1008	CSMF	0.92	0.22	0.77	1.08	0.56	0.88	0.77	0.97	-0.74	1.21	1.12	1.34	1.32	0.80	-0.03	0.46	0.96	0.71	0.83	0.50	-0.27	1.23	2.39	0.78
1012	CSMF	0.29	-0.55	0.11	0.07	-0.19	0.36	0.24	0.36	-1.26	0.36	0.23	0.27	0.20	0.37	-0.87	-0.25	0.61	0.21	0.50	0.08	-0.75	0.16	1.25	0.08
5014	CSMF	-0.07	-0.97	-0.24	-0.39	-0.56	0.12	-0.01	0.07	-1.57	-0.08	-0.25	-0.26	-0.36	0.15	-1.30	-0.64	0.48	-0.04	0.33	-0.16	-1.07	-0.35	0.71	-0.28
5021	CSMF	-0.66	-1.94	-0.92	-1.02	-1.15	-0.18	-0.32	-0.36	-2.32	-0.64	-0.86	-1.02	-1.15	-0.33	-2.35	-1.49	0.25	-0.58	-0.06	-0.77	-1.99	-1.08	0.09	-0.91
6011	CSMF	0.12	0.39	0.34	-0.31	-0.38	-0.18	-0.24	0.01	-0.67	-0.21	-0.33	-0.05	-0.10	0.45	0.33	0.41	0.45	0.48	0.61	0.59	0.44	-0.08	0.45	0.11
6013	CSMF	-0.08	0.02	0.13	-0.50	-0.56	-0.32	-0.37	-0.14	-0.90	-0.40	-0.54	-0.32	-0.39	0.30	-0.06	0.16	0.39	0.36	0.52	0.44	0.12	-0.32	0.21	-0.10
6020	CSMF	-0.34	-0.45	-0.13	-0.74	-0.78	-0.51	-0.56	-0.34	-1.18	-0.64	-0.80	-0.66	-0.74	0.10	-0.55	-0.14	0.31	0.21	0.41	0.25	-0.27	-0.65	-0.09	-0.36
6021	CSMF	-0.36	-0.95	-0.34	-0.77	-0.83	-0.29	-0.36	-0.23	-1.54	-0.56	-0.74	-0.71	-0.82	0.07	-1.19	-0.61	0.37	0.00	0.33	-0.06	-0.87	-0.72	0.07	-0.48
1009	CSMF	0.44	-0.64	0.18	0.63	0.10	0.68	0.55	0.63	-1.42	0.82	0.69	0.79	0.75	0.36	-0.97	-0.28	0.76	0.20	0.45	-0.09	-1.15	0.69	2.01	0.27
1010	CSMF	0.19	-1.12	-0.13	0.56	-0.08	0.65	0.50	0.52	-1.86	0.72	0.55	0.65	0.59	0.10	-1.46	-0.73	0.68	-0.09	0.20	-0.48	-1.76	0.55	2.03	0.03
9101	COMF	1.00	1.52	1.14	0.68	0.48	0.49	0.39	0.73	0.08	0.78	0.73	1.12	1.09	1.03	1.49	1.34	0.78	1.05	1.03	1.17	1.36	1.00	1.60	0.96
9103	COMF	0.17	0.76	0.46	-0.25	-0.32	-0.17	-0.23	0.03	-0.49	-0.18	-0.29	0.04	0.00	0.49	0.80	0.67	0.46	0.56	0.64	0.70	0.82	0.01	0.46	0.22
9105	COMF	-0.27	0.22	0.08	-0.66	-0.70	-0.57	-0.60	-0.36	-0.84	-0.63	-0.76	-0.51	-0.57	0.14	0.30	0.32	0.28	0.33	0.45	0.46	0.41	-0.50	-0.10	-0.18
9107	COMF	-0.42	-0.03	-0.07	-0.79	-0.83	-0.71	-0.74	-0.49	-0.99	-0.77	-0.91	-0.71	-0.77	0.00	0.05	0.17	0.20	0.24	0.37	0.36	0.20	-0.70	-0.29	-0.33
9102	COMF	0.84	1.46	1.02	0.48	0.31	0.34	0.26	0.58	0.01	0.57	0.50	0.91	0.87	0.93	1.46	1.25	0.70	0.95	0.95	1.10	1.35	0.80	1.35	0.83
9104	COMF	0.11	0.72	0.41	-0.31	-0.37	-0.23	-0.28	-0.02	-0.53	-0.25	-0.36	-0.04	-0.08	0.44	0.78	0.64	0.44	0.53	0.61	0.68	0.80	-0.06	0.38	0.17
9106	COMF	-0.01	0.26	0.23	-0.43	-0.49	-0.27	-0.33	-0.09	-0.77	-0.34	-0.47	-0.23	-0.29	0.35	0.25	0.33	0.42	0.42	0.56	0.51	0.36	-0.24	0.27	0.00
9108	COMF	-0.28	-0.03	0.01	-0.67	-0.72	-0.52	-0.57	-0.33	-0.96	-0.61	-0.75	-0.55	-0.62	0.14	-0.01	0.15	0.30	0.29	0.44	0.39	0.15	-0.54	-0.08	-0.23
9201	COMF	0.93	1.56	1.08	0.59	0.41	0.41	0.32	0.66	0.05	0.68	0.61	1.03	0.98	0.99	1.56	1.33	0.73	1.01	0.99	1.16	1.42	0.90	1.47	0.91
9203	COMF	0.40	0.89	0.63	-0.01	-0.11	0.04	-0.03	0.24	-0.36	0.08	-0.02	0.32	0.28	0.65	0.89	0.78	0.55	0.67	0.74	0.80	0.89	0.27	0.79	0.41
9205	COMF	-0.12	0.31	0.18	-0.53	-0.58	-0.42	-0.46	-0.22	-0.77	-0.48	-0.60	-0.35	-0.40	0.27	0.35	0.37	0.36	0.40	0.51	0.52	0.46	-0.34	0.09	-0.06
9207	COMF	-0.30	0.03	0.02	-0.69	-0.73	-0.57	-0.61	-0.36	-0.94	-0.64	-0.78	-0.57	-0.63	0.12	0.07	0.19	0.28	0.30	0.44	0.40	0.22	-0.56	-0.12	-0.24
9202	COMF	0.83	1.50	1.01	0.46	0.30	0.33	0.24	0.57	0.00	0.55	0.48	0.90	0.85	0.93	1.52	1.27	0.69	0.95	0.94	1.11	1.40	0.78	1.32	0.82
9204	COMF	0.43	0.90	0.64	0.02	-0.08	0.06	-0.01	0.27	-0.35	0.12	0.02	0.35	0.32	0.66	0.89	0.79	0.56	0.68	0.75	0.81	0.89	0.30	0.83	0.43
9206	COMF	0.06	0.31	0.27	-0.36	-0.43	-0.20	-0.26	-0.02	-0.74	-0.26	-0.39	-0.14	-0.20	0.40	0.28	0.36	0.45	0.44	0.59	0.54	0.39	-0.16	0.37	0.06
9208	COMF	-0.29	0.03	0.02	-0.69	-0.73	-0.56	-0.60	-0.36	-0.94	-0.64	-0.78	-0.57	-0.63	0.12	0.06	0.19	0.28	0.30	0.44	0.40	0.22	-0.55	-0.11	-0.23
	Average	0.14	0.07	0.24	-0.16	-0.32	-0.01	-0.09	0.12	-0.90	-0.02	-0.15	0.05	-0.01	0.38	-0.04	0.20	0.50	0.38	0.55	0.39	0.03	0.00	0.72	0.09

Table 16 : PMF_R values (τ = 150 years) at high hazard locations

PMF_R Values of High Hazard Locations

For high hazard locations and with a τ value of 150 years, the PMF_R value averaged over all the building models and all the locations is 0.09 ≈ 0. This indicates that, the collapse probabilities conditioned on MCE_R shaking level and the collapse risks for a 150 year period are similar.

However, this is not the case for high hazard locations when τ = 50 years. Also, as we can see from tables 16 and 17, several values are yellow colored. This indicates that for several building-location combinations, the PMF_R is not near zero. Hence, to address the variation in the values, a deterministic sensitivity study is performed to check for the parameters to which the PMF_R value is most sensitive.

The following tables show the collapse probabilities, collapse risks, scores, risk scores and PMF_R values for the buildings at medium hazard locations. Table 19 shows the score calculated using collapse probabilities at medium hazard locations. This table is color coded so that as the color varies from red color for the lowest value of score in the table to green color which is the highest value of score in the table. This representation is chosen to show that a lower value of score represents a higher probability of collapse under MCE_R shaking level ground motion. In the table, we can see that the collapse probabilities of COMF buildings are higher when compared with the collapse probabilities of CSMF buildings. This is because CSMF building models are designed better to withstand earthquakes.

Tables 21 and 22 show the risk score calculated for 50 year period and 150 year period respectively using collapse risk, at medium hazard locations. These tables are also color coded in a similar way as Table 19. In this table, the color varies from red color for the lowest value of risk score in the table to green color which is the highest value of risk score in the table. Low value of risk score indicates a higher collapse frequency in τ years and vice-versa. As we can see from the tables, CSMF frames have a lower collapse risk than the COMF frames. This is because CSMF frames are designed better to resist earthquakes through ductile detailing.

Tables 23 and 24 show the PMF_R values at medium hazard locations for 50 year period and 150 year period respectively. These tables are color coded so the green color indicates that PMF_R is equal to 0 and yellow color indicates the negative and positive PMF_R values farthest from zero. A whole numbered PMF_R of 0, 1, 2 etc. would give a physical meaning to PMF_R in comparison of collapse probability and collapse risk. In this study, a PMF_R value varying ±0.25 from a whole numbered value of PMF_R is assumed to be acceptable.

Collapse probability of buildings given MCER level shaking(medium hazard)																							
		Medium hazard location																					
Archetype	Model type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Average
1003	CSMF	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	0.00	0.00
1011	CSMF	0.02	0.04	0.00	0.00	0.01	0.00	0.00	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
5013	CSMF	0.01	0.02	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
5020	CSMF	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	0.00	0.00
1008	CSMF	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	0.00	0.00
1012	CSMF	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	0.00	0.00
5014	CSMF	0.01	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	0.00	0.00
5021	CSMF	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
6011	CSMF	0.38	0.49	0.04	0.11	0.29	0.01	0.21	0.04	0.00	0.03	0.00	0.29	0.08	0.23	0.05	0.10	0.06	0.10	0.01	0.00	0.00	0.12
6013	CSMF	0.29	0.40	0.02	0.07	0.21	0.00	0.15	0.02	0.00	0.02	0.00	0.21	0.05	0.17	0.03	0.07	0.04	0.07	0.01	0.00	0.00	0.09
6020	CSMF	0.21	0.30	0.01	0.04	0.15	0.00	0.09	0.01	0.00	0.01	0.00	0.14	0.03	0.11	0.02	0.04	0.02	0.04	0.00	0.00	0.00	0.06
6021	CSMF	0.04	0.06	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
1009	CSMF	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
1010	CSMF	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
9101	COMF	0.31	0.31	0.05	0.12	0.28	0.01	0.21	0.05	0.01	0.05	0.00	0.26	0.03	0.13	0.01	0.04	0.03	0.07	0.02	0.01	0.01	0.10
9103	COMF	0.68	0.76	0.21	0.36	0.60	0.08	0.51	0.21	0.06	0.20	0.04	0.59	0.31	0.54	0.24	0.36	0.27	0.36	0.10	0.06	0.06	0.31
9105	COMF	0.73	0.80	0.26	0.42	0.66	0.10	0.57	0.26	0.08	0.24	0.05	0.65	0.37	0.60	0.29	0.41	0.33	0.42	0.13	0.08	0.08	0.36
9107	COMF	0.68	0.76	0.21	0.36	0.59	0.08	0.50	0.21	0.06	0.19	0.04	0.59	0.31	0.54	0.24	0.35	0.27	0.35	0.10	0.06	0.06	0.31
9102	COMF	0.46	0.45	0.11	0.21	0.42	0.03	0.33	0.10	0.02	0.10	0.00	0.39	0.06	0.23	0.03	0.08	0.06	0.14	0.04	0.02	0.02	0.16
9104	COMF	0.74	0.81	0.27	0.43	0.66	0.10	0.57	0.26	0.08	0.25	0.05	0.66	0.37	0.61	0.30	0.42	0.33	0.42	0.13	0.08	0.08	0.36
9106	COMF	0.38	0.48	0.06	0.13	0.30	0.01	0.23	0.06	0.01	0.05	0.01	0.30	0.10	0.25	0.07	0.13	0.09	0.13	0.02	0.01	0.01	0.13
9108	COMF	0.44	0.54	0.08	0.17	0.36	0.02	0.27	0.08	0.01	0.07	0.01	0.35	0.13	0.30	0.09	0.16	0.11	0.16	0.03	0.01	0.01	0.16
9201	COMF	0.39	0.38	0.10	0.18	0.38	0.03	0.32	0.10	0.02	0.09	0.00	0.33	0.04	0.18	0.02	0.05	0.04	0.10	0.04	0.02	0.02	0.13
9203	COMF	0.48	0.58	0.10	0.19	0.40	0.03	0.31	0.09	0.02	0.09	0.01	0.39	0.16	0.34	0.12	0.19	0.13	0.19	0.04	0.02	0.02	0.19
9205	COMF	0.60	0.69	0.16	0.29	0.52	0.05	0.43	0.16	0.04	0.14	0.02	0.51	0.24	0.46	0.18	0.28	0.21	0.28	0.07	0.04	0.04	0.26
9207	COMF	0.54	0.63	0.12	0.23	0.45	0.04	0.36	0.12	0.03	0.11	0.02	0.45	0.20	0.39	0.14	0.23	0.17	0.23	0.05	0.03	0.03	0.22
9202	COMF	0.48	0.47	0.14	0.25	0.47	0.04	0.40	0.14	0.03	0.13	0.00	0.41	0.07	0.25	0.04	0.08	0.07	0.15	0.06	0.03	0.03	0.18
9204	COMF	0.45	0.55	0.09	0.17	0.37	0.02	0.29	0.08	0.02	0.08	0.01	0.37	0.14	0.32	0.10	0.17	0.12	0.17	0.03	0.02	0.02	0.17
9206	COMF	0.34	0.43	0.05	0.11	0.26	0.01	0.19	0.05	0.01	0.04	0.00	0.26	0.09	0.22	0.06	0.11	0.07	0.11	0.02	0.01	0.01	0.12
9208	COMF	0.53	0.63	0.12	0.23	0.45	0.04	0.36	0.12	0.03	0.11	0.01	0.44	0.19	0.39	0.14	0.22	0.16	0.23	0.05	0.02	0.02	0.21
	Average	0.31	0.35	0.07	0.14	0.26	0.02	0.21	0.07	0.02	0.07	0.01	0.25	0.10	0.21	0.07	0.12	0.09	0.12	0.03	0.02	0.02	0.12

Table 17 : Collapse probabilities conditioned on MCE_R S_{MT} shaking at medium hazard locations

Score based on collapse probability																							
		Medium hazard location																					
Archetype	Model type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Average
1003	CSMF	2.31	1.98	4.55	3.68	2.63	6.00	3.01	4.59	6.34	4.69	6.99	2.65	3.93	2.87	4.37	3.70	4.15	3.69	5.65	6.39	6.40	4.31
1011	CSMF	1.71	1.43	3.65	2.88	1.98	4.95	2.31	3.68	5.25	3.77	5.82	2.00	3.11	2.19	3.47	2.90	3.30	2.90	4.63	5.29	5.31	3.45
5013	CSMF	2.04	1.73	4.15	3.33	2.35	5.54	2.70	4.19	5.86	4.29	6.47	2.36	3.57	2.57	3.96	3.35	3.78	3.34	5.21	5.91	5.93	3.93
5020	CSMF	2.41	2.07	4.69	3.81	2.74	6.17	3.13	4.74	6.51	4.84	7.15	2.76	4.07	2.99	4.49	3.83	4.29	3.82	5.82	6.56	6.58	4.45
1008	CSMF	2.57	2.21	4.92	4.01	2.91	6.44	3.31	4.97	6.79	5.07	7.47	2.93	4.28	3.17	4.74	4.04	4.51	4.03	6.08	6.84	6.86	4.68
1012	CSMF	2.32	1.99	4.57	3.70	2.65	6.03	3.03	4.61	6.37	4.71	7.00	2.67	3.96	2.89	4.37	3.72	4.18	3.71	5.68	6.41	6.43	4.33
5014	CSMF	2.26	1.94	4.48	3.62	2.59	5.93	2.96	4.52	6.26	4.62	6.89	2.60	3.87	2.82	4.29	3.64	4.09	3.63	5.58	6.31	6.33	4.25
5021	CSMF	2.89	2.51	5.38	4.42	3.26	6.97	3.68	5.43	7.33	5.54	8.01	3.28	4.71	3.53	5.16	4.45	4.95	4.44	6.59	7.38	7.40	5.11
6011	CSMF	0.42	0.31	1.39	0.97	0.54	2.18	0.68	1.42	2.37	1.47	2.74	0.54	1.09	0.63	1.29	0.99	1.20	0.98	1.98	2.40	2.41	1.33
6013	CSMF	0.53	0.40	1.63	1.16	0.67	2.48	0.84	1.65	2.69	1.71	3.08	0.68	1.30	0.77	1.52	1.18	1.41	1.17	2.27	2.72	2.73	1.55
6020	CSMF	0.68	0.52	1.91	1.39	0.83	2.84	1.03	1.93	3.06	2.00	3.48	0.84	1.54	0.96	1.79	1.41	1.67	1.40	2.61	3.09	3.10	1.81
6021	CSMF	1.44	1.19	3.22	2.51	1.68	4.44	1.98	3.25	4.72	3.33	5.26	1.70	2.72	1.87	3.05	2.53	2.89	2.52	4.14	4.76	4.78	3.05
1009	CSMF	3.39	2.97	6.08	5.05	3.79	7.77	4.25	6.13	8.15	6.24	8.87	3.81	5.36	4.08	5.85	5.08	5.62	5.07	7.37	8.21	8.23	5.78
1010	CSMF	4.16	3.69	7.13	6.01	4.61	8.97	5.12	7.19	9.38	7.31	10.16	4.64	6.34	4.94	6.88	6.04	6.63	6.03	8.53	9.44	9.46	6.79
9101	COMF	0.50	0.51	1.28	0.93	0.55	1.92	0.68	1.30	2.07	1.34	3.33	0.59	1.54	0.87	1.87	1.45	1.55	1.14	1.76	2.09	2.10	1.40
9103	COMF	0.17	0.12	0.67	0.44	0.22	1.11	0.30	0.68	1.23	0.71	1.44	0.23	0.51	0.27	0.61	0.45	0.56	0.45	1.00	1.24	1.25	0.65
9105	COMF	0.14	0.09	0.58	0.38	0.18	0.99	0.25	0.59	1.10	0.62	1.30	0.19	0.43	0.22	0.53	0.38	0.49	0.38	0.89	1.11	1.12	0.57
9107	COMF	0.17	0.12	0.67	0.45	0.23	1.12	0.30	0.69	1.23	0.71	1.45	0.23	0.51	0.27	0.62	0.45	0.57	0.45	1.01	1.25	1.26	0.66
9102	COMF	0.34	0.35	0.97	0.68	0.38	1.51	0.48	0.98	1.65	1.02	2.77	0.40	1.19	0.63	1.47	1.12	1.20	0.85	1.38	1.67	1.67	1.08
9104	COMF	0.13	0.09	0.57	0.37	0.18	0.98	0.24	0.58	1.08	0.61	1.29	0.18	0.43	0.22	0.52	0.38	0.48	0.37	0.87	1.10	1.10	0.56
9106	COMF	0.42	0.32	1.22	0.88	0.52	1.85	0.64	1.24	2.00	1.28	2.29	0.53	0.98	0.60	1.14	0.89	1.07	0.89	1.69	2.02	2.03	1.17
9108	COMF	0.36	0.27	1.10	0.78	0.45	1.68	0.56	1.11	1.83	1.15	2.10	0.45	0.87	0.52	1.02	0.79	0.95	0.79	1.54	1.85	1.86	1.05
9201	COMF	0.41	0.42	1.01	0.74	0.42	1.56	0.50	1.02	1.70	1.06	3.03	0.49	1.35	0.74	1.65	1.27	1.36	0.98	1.42	1.72	1.73	1.17
9203	COMF	0.31	0.24	1.01	0.71	0.40	1.57	0.50	1.02	1.71	1.06	1.97	0.40	0.80	0.46	0.94	0.72	0.87	0.72	1.43	1.73	1.74	0.97
9205	COMF	0.22	0.16	0.80	0.54	0.29	1.29	0.37	0.81	1.41	0.84	1.65	0.29	0.61	0.34	0.74	0.55	0.68	0.55	1.16	1.43	1.43	0.77
9207	COMF	0.27	0.20	0.91	0.63	0.34	1.44	0.44	0.92	1.57	0.96	1.82	0.35	0.71	0.40	0.84	0.64	0.78	0.64	1.31	1.59	1.59	0.87
9202	COMF	0.32	0.33	0.84	0.61	0.33	1.35	0.40	0.85	1.47	0.89	2.71	0.39	1.15	0.60	1.43	1.08	1.16	0.82	1.22	1.49	1.50	1.00
9204	COMF	0.34	0.26	1.07	0.76	0.43	1.65	0.54	1.09	1.79	1.12	2.06	0.44	0.85	0.50	1.00	0.77	0.93	0.76	1.50	1.81	1.82	1.02
9206	COMF	0.47	0.37	1.33	0.97	0.58	1.98	0.71	1.34	2.13	1.39	2.44	0.59	1.07	0.66	1.24	0.98	1.16	0.97	1.82	2.16	2.16	1.26
9208	COMF	0.27	0.20	0.92	0.64	0.35	1.46	0.45	0.94	1.59	0.97	1.84	0.36	0.72	0.41	0.86	0.65	0.79	0.65	1.32	1.61	1.61	0.89
	Average	1.13	0.97	2.42	1.90	1.30	3.34	1.51	2.45	3.55	2.51	4.10	1.32	2.12	1.47	2.39	1.98	2.24	1.94	3.11	3.59	3.60	2.33

Table 18 : Score calculated using collapse probabilities at medium hazard locations

Annual collapse risk to a building due to seismic hazard at a location																								
		Medium hazard locations																						
Archetype	Model type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21		Average
1003	CSMF	6E-06	2E-06	9E-07	8E-07	3E-06	5E-07	5E-06	1E-05	7E-07	2E-06	2E-07	4E-06	6E-07	2E-06	4E-07	7E-07	8E-07	1E-06	2E-06	2E-06	1E-06		2E-06
1011	CSMF	1E-04	1E-04	2E-05	2E-05	7E-05	8E-06	7E-05	6E-05	8E-06	2E-05	3E-06	9E-05	2E-05	6E-05	1E-05	2E-05	2E-05	3E-05	2E-05	2E-05	1E-05		4E-05
5013	CSMF	2E-04	3E-04	3E-05	4E-05	1E-04	1E-05	1E-04	8E-05	1E-05	4E-05	6E-06	2E-04	4E-05	1E-04	3E-05	5E-05	3E-05	5E-05	3E-05	3E-05	2E-05		7E-05
5020	CSMF	4E-04	8E-04	7E-05	1E-04	3E-04	3E-05	2E-04	1E-04	3E-05	8E-05	2E-05	3E-04	1E-04	3E-04	8E-05	1E-04	9E-05	1E-04	6E-05	5E-05	4E-05		2E-04
1008	CSMF	4E-06	1E-06	6E-07	5E-07	2E-06	3E-07	3E-06	9E-06	5E-07	1E-06	1E-07	3E-06	4E-07	1E-06	3E-07	5E-07	6E-07	9E-07	1E-06	2E-06	1E-06		2E-06
1012	CSMF	5E-05	4E-05	7E-06	8E-06	3E-05	3E-06	3E-05	4E-05	4E-06	1E-05	1E-06	4E-05	8E-06	3E-05	5E-06	9E-06	7E-06	1E-05	9E-06	9E-06	7E-06		2E-05
5014	CSMF	2E-04	2E-04	2E-05	3E-05	1E-04	1E-05	9E-05	7E-05	1E-05	3E-05	5E-06	1E-04	3E-05	9E-05	2E-05	4E-05	3E-05	4E-05	2E-05	2E-05	2E-05		5E-05
5021	CSMF	3E-04	5E-04	4E-05	6E-05	2E-04	2E-05	2E-04	9E-05	2E-05	5E-05	1E-05	2E-04	7E-05	2E-04	5E-05	8E-05	5E-05	8E-05	4E-05	3E-05	3E-05		1E-04
6011	CSMF	1E-03	3E-03	2E-04	3E-04	9E-04	9E-05	5E-04	2E-04	9E-05	2E-04	6E-05	8E-04	3E-04	6E-04	2E-04	4E-04	3E-04	3E-04	1E-04	1E-04	1E-04		5E-04
6013	CSMF	2E-03	5E-03	3E-04	6E-04	2E-03	2E-04	8E-04	3E-04	1E-04	3E-04	1E-04	1E-03	5E-04	1E-03	4E-04	6E-04	4E-04	6E-04	2E-04	2E-04	1E-04		8E-04
6020	CSMF	3E-03	1E-02	7E-04	1E-03	3E-03	3E-04	1E-03	5E-04	3E-04	6E-04	2E-04	2E-03	9E-04	2E-03	7E-04	1E-03	8E-04	1E-03	4E-04	3E-04	3E-04		1E-03
6021	CSMF	1E-03	4E-03	2E-04	4E-04	1E-03	1E-04	6E-04	2E-04	1E-04	2E-04	7E-05	8E-04	4E-04	7E-04	3E-04	4E-04	3E-04	4E-04	2E-04	1E-04	1E-04		5E-04
1009	CSMF	3E-06	1E-06	5E-07	5E-07	2E-06	3E-07	3E-06	8E-06	4E-07	1E-06	1E-07	2E-06	3E-07	1E-06	2E-07	4E-07	5E-07	8E-07	1E-06	2E-06	1E-06		1E-06
1010	CSMF	1E-06	4E-07	2E-07	2E-07	8E-07	1E-07	1E-06	5E-06	2E-07	6E-07	6E-08	1E-06	1E-07	4E-07	9E-08	1E-07	2E-07	4E-07	7E-07	9E-07	6E-07		7E-07
9101	COMF	9E-05	1E-04	1E-05	2E-05	6E-05	7E-06	5E-05	5E-05	7E-06	2E-05	3E-06	7E-05	2E-05	5E-05	1E-05	2E-05	1E-05	2E-05	1E-05	1E-05	1E-05		3E-05
9103	COMF	1E-03	3E-03	2E-04	4E-04	9E-04	1E-04	5E-04	2E-04	9E-05	2E-04	6E-05	7E-04	3E-04	6E-04	2E-04	4E-04	3E-04	4E-04	1E-04	1E-04	1E-04		5E-04
9105	COMF	3E-03	1E-02	9E-04	2E-03	4E-03	4E-04	2E-03	6E-04	4E-04	7E-04	3E-04	2E-03	1E-03	2E-03	9E-04	1E-03	1E-03	1E-03	4E-04	3E-04	3E-04		2E-03
9107	COMF	5E-03	2E-02	1E-03	3E-03	6E-03	7E-04	2E-03	9E-04	6E-04	1E-03	5E-04	2E-03	1E-03	2E-03	1E-03	2E-03	2E-03	2E-03	7E-04	5E-04	5E-04		3E-03
9102	COMF	2E-04	3E-04	3E-05	4E-05	1E-04	1E-05	9E-05	6E-05	1E-05	3E-05	6E-06	1E-04	4E-05	1E-04	3E-05	4E-05	3E-05	5E-05	2E-05	2E-05	2E-05		6E-05
9104	COMF	1E-03	4E-03	3E-04	4E-04	1E-03	1E-04	6E-04	2E-04	1E-04	2E-04	8E-05	8E-04	4E-04	7E-04	3E-04	4E-04	3E-04	4E-04	2E-04	1E-04	1E-04		6E-04
9106	COMF	1E-03	5E-03	3E-04	5E-04	1E-03	1E-04	7E-04	3E-04	1E-04	3E-04	9E-05	9E-04	4E-04	8E-04	3E-04	5E-04	4E-04	5E-04	2E-04	1E-04	1E-04		7E-04
9108	COMF	3E-03	1E-02	7E-04	1E-03	3E-03	3E-04	1E-03	5E-04	3E-04	6E-04	2E-04	2E-03	9E-04	2E-03	8E-04	1E-03	9E-04	1E-03	4E-04	3E-04	3E-04		2E-03
9201	COMF	1E-04	2E-04	2E-05	3E-05	8E-05	9E-06	7E-05	5E-05	9E-06	2E-05	4E-06	9E-05	3E-05	7E-05	2E-05	3E-05	2E-05	3E-05	2E-05	2E-05	1E-05		4E-05
9203	COMF	5E-04	1E-03	9E-05	1E-04	4E-04	4E-05	3E-04	1E-04	4E-05	1E-04	2E-05	4E-04	1E-04	3E-04	1E-04	2E-04	1E-04	2E-04	7E-05	6E-05	5E-05		2E-04
9205	COMF	2E-03	8E-03	5E-04	9E-04	2E-03	2E-04	1E-03	4E-04	2E-04	4E-04	2E-04	1E-03	7E-04	1E-03	6E-04	8E-04	6E-04	8E-04	3E-04	2E-04	2E-04		1E-03
9207	COMF	3E-03	1E-02	8E-04	2E-03	4E-03	4E-04	2E-03	6E-04	4E-04	7E-04	3E-04	2E-03	1E-03	2E-03	9E-04	1E-03	1E-03	1E-03	4E-04	3E-04	3E-04		2E-03
9202	COMF	2E-04	3E-04	3E-05	4E-05	1E-04	1E-05	1E-04	7E-05	1E-05	3E-05	6E-06	1E-04	4E-05	1E-04	3E-05	5E-05	3E-05	5E-05	2E-05	2E-05	2E-05		6E-05
9204	COMF	5E-04	1E-03	8E-05	1E-04	4E-04	4E-05	3E-04	1E-04	4E-05	9E-05	2E-05	4E-04	1E-04	3E-04	1E-04	1E-04	1E-04	1E-04	6E-05	5E-05	4E-05		2E-04
9206	COMF	1E-03	3E-03	2E-04	4E-04	1E-03	1E-04	6E-04	2E-04	1E-04	2E-04	7E-05	8E-04	3E-04	7E-04	3E-04	4E-04	3E-04	4E-04	1E-04	1E-04	1E-04		5E-04
9208	COMF	3E-03	1E-02	8E-04	2E-03	4E-03	4E-04	2E-03	6E-04	3E-04	7E-04	3E-04	2E-03	1E-03	2E-03	9E-04	1E-03	1E-03	1E-03	4E-04	3E-04	3E-04		2E-03
	Average	1E-03	4E-03	3E-04	5E-04	1E-03	1E-04	6E-04	2E-04	1E-04	2E-04	9E-05	7E-04	3E-04	6E-04	3E-04	4E-04	3E-04	4E-04	2E-04	1E-04	1E-04		6E-04

Table 19 : Annual collapse risk calculated using hazard curves at medium hazard locations

Risk Score based on collapse risk for a 50 year period																							
		SR (MH)																					
Archetype	Model type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Average
1003	CSMF	3.54	3.94	4.36	4.40	3.79	4.64	3.64	3.26	4.47	4.08	5.05	3.68	4.50	3.95	4.67	4.44	4.38	4.18	4.04	3.94	4.13	4.15
1011	CSMF	2.25	2.20	3.09	2.99	2.48	3.40	2.49	2.56	3.40	2.97	3.80	2.37	2.96	2.50	3.13	2.90	3.06	2.84	3.07	3.07	3.20	2.89
5013	CSMF	2.00	1.85	2.82	2.69	2.20	3.14	2.25	2.42	3.16	2.73	3.50	2.12	2.66	2.22	2.81	2.60	2.76	2.56	2.85	2.88	2.99	2.63
5020	CSMF	1.68	1.38	2.46	2.28	1.82	2.79	1.95	2.23	2.82	2.40	3.09	1.79	2.27	1.88	2.40	2.21	2.37	2.19	2.55	2.61	2.70	2.28
1008	CSMF	3.71	4.16	4.52	4.58	3.95	4.80	3.79	3.36	4.60	4.21	5.19	3.85	4.70	4.15	4.85	4.63	4.53	4.34	4.16	4.05	4.24	4.30
1012	CSMF	2.61	2.69	3.46	3.40	2.86	3.76	2.81	2.75	3.73	3.30	4.19	2.74	3.40	2.89	3.57	3.34	3.46	3.23	3.36	3.33	3.48	3.26
5014	CSMF	2.11	2.00	2.94	2.82	2.32	3.25	2.35	2.48	3.27	2.83	3.63	2.23	2.79	2.34	2.95	2.73	2.89	2.68	2.95	2.96	3.09	2.74
5021	CSMF	1.86	1.64	2.66	2.51	2.03	2.99	2.12	2.34	3.01	2.58	3.32	1.97	2.48	2.07	2.63	2.43	2.59	2.40	2.72	2.76	2.87	2.48
6011	CSMF	1.28	0.83	1.99	1.78	1.34	2.33	1.57	1.97	2.37	1.99	2.55	1.43	1.81	1.49	1.92	1.75	1.89	1.76	2.17	2.27	2.32	1.85
6013	CSMF	1.10	0.57	1.77	1.54	1.11	2.10	1.39	1.82	2.15	1.80	2.29	1.27	1.61	1.32	1.70	1.55	1.66	1.56	1.99	2.10	2.13	1.64
6020	CSMF	0.87	0.26	1.48	1.23	0.83	1.81	1.16	1.62	1.86	1.56	1.97	1.09	1.36	1.12	1.44	1.30	1.39	1.32	1.75	1.87	1.87	1.39
6021	CSMF	1.23	0.75	1.93	1.71	1.28	2.26	1.52	1.93	2.31	1.94	2.47	1.38	1.75	1.44	1.86	1.69	1.82	1.70	2.12	2.22	2.26	1.79
1009	CSMF	3.78	4.25	4.58	4.65	4.02	4.86	3.85	3.40	4.65	4.26	5.24	3.91	4.77	4.23	4.92	4.70	4.59	4.40	4.20	4.09	4.29	4.36
1010	CSMF	4.21	4.74	4.95	5.05	4.39	5.24	4.21	3.65	4.94	4.56	5.55	4.30	5.20	4.70	5.33	5.13	4.91	4.74	4.47	4.35	4.55	4.72
9101	COMF	2.35	2.25	3.17	3.06	2.56	3.49	2.58	2.64	3.49	3.06	3.87	2.47	3.04	2.59	3.20	2.98	3.13	2.93	3.16	3.16	3.29	2.97
9103	COMF	1.28	0.80	1.98	1.76	1.33	2.31	1.57	1.97	2.35	1.99	2.52	1.44	1.81	1.50	1.91	1.75	1.87	1.76	2.17	2.27	2.31	1.84
9105	COMF	0.79	0.14	1.37	1.11	0.72	1.69	1.08	1.53	1.75	1.47	1.85	1.04	1.29	1.06	1.35	1.22	1.29	1.24	1.65	1.78	1.77	1.30
9107	COMF	0.63	-0.06	1.17	0.90	0.52	1.47	0.91	1.36	1.54	1.30	1.63	0.91	1.13	0.93	1.18	1.06	1.11	1.07	1.47	1.60	1.58	1.12
9102	COMF	2.09	1.90	2.90	2.75	2.27	3.22	2.34	2.49	3.23	2.81	3.56	2.20	2.73	2.31	2.88	2.68	2.83	2.64	2.93	2.96	3.07	2.70
9104	COMF	1.21	0.70	1.88	1.66	1.23	2.22	1.50	1.91	2.26	1.91	2.41	1.37	1.72	1.43	1.82	1.66	1.78	1.67	2.09	2.19	2.23	1.76
9106	COMF	1.16	0.63	1.82	1.59	1.17	2.16	1.45	1.87	2.20	1.86	2.34	1.33	1.67	1.38	1.77	1.61	1.72	1.62	2.04	2.15	2.18	1.70
9108	COMF	0.85	0.21	1.44	1.18	0.79	1.76	1.13	1.58	1.82	1.53	1.92	1.08	1.34	1.11	1.41	1.28	1.35	1.29	1.71	1.84	1.83	1.36
9201	COMF	2.21	2.06	3.03	2.90	2.41	3.34	2.45	2.56	3.35	2.93	3.70	2.33	2.88	2.44	3.03	2.82	2.97	2.77	3.04	3.05	3.17	2.83
9203	COMF	1.59	1.21	2.33	2.14	1.69	2.66	1.86	2.18	2.70	2.30	2.92	1.71	2.15	1.79	2.27	2.09	2.24	2.09	2.47	2.54	2.61	2.17
9205	COMF	0.97	0.38	1.59	1.35	0.94	1.92	1.26	1.70	1.97	1.66	2.09	1.18	1.47	1.22	1.55	1.41	1.50	1.42	1.85	1.96	1.97	1.49
9207	COMF	0.79	0.15	1.37	1.11	0.72	1.69	1.08	1.53	1.75	1.47	1.85	1.04	1.29	1.06	1.35	1.22	1.29	1.24	1.66	1.78	1.77	1.30
9202	COMF	2.06	1.86	2.87	2.72	2.24	3.18	2.31	2.48	3.20	2.78	3.52	2.17	2.70	2.28	2.85	2.64	2.80	2.61	2.90	2.93	3.05	2.67
9204	COMF	1.63	1.27	2.38	2.19	1.74	2.71	1.90	2.21	2.75	2.35	2.98	1.75	2.20	1.83	2.32	2.14	2.29	2.13	2.51	2.57	2.65	2.21
9206	COMF	1.26	0.76	1.94	1.72	1.29	2.28	1.54	1.95	2.32	1.96	2.48	1.42	1.78	1.48	1.88	1.72	1.84	1.73	2.14	2.24	2.28	1.81
9208	COMF	0.80	0.15	1.38	1.12	0.73	1.70	1.08	1.54	1.76	1.48	1.86	1.04	1.30	1.07	1.36	1.23	1.30	1.25	1.66	1.79	1.78	1.30
	Average	1.80	1.52	2.52	2.36	1.89	2.84	2.04	2.24	2.84	2.47	3.11	1.95	2.43	2.06	2.54	2.36	2.45	2.31	2.60	2.64	2.72	2.37

Table 20 : Risk score calculated for 50 year period using collapse risk, at medium hazard locations

Risk Score based on collapse risk for a 150 year period																							
		SR (MH)																					
Archetype	Model type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Average
1003	CSMF	3.06	3.46	3.88	3.93	3.31	4.16	3.16	2.78	3.99	3.60	4.57	3.20	4.02	3.47	4.19	3.96	3.91	3.70	3.57	3.46	3.65	3.67
1011	CSMF	1.78	1.72	2.61	2.51	2.00	2.92	2.01	2.08	2.93	2.49	3.32	1.89	2.49	2.02	2.65	2.43	2.58	2.36	2.59	2.59	2.73	2.41
5013	CSMF	1.53	1.37	2.35	2.21	1.72	2.66	1.78	1.94	2.68	2.25	3.03	1.64	2.18	1.75	2.34	2.12	2.29	2.08	2.37	2.40	2.52	2.15
5020	CSMF	1.20	0.91	1.98	1.80	1.34	2.31	1.47	1.75	2.34	1.92	2.61	1.31	1.79	1.40	1.93	1.73	1.89	1.72	2.07	2.13	2.23	1.80
1008	CSMF	3.24	3.68	4.04	4.10	3.47	4.32	3.32	2.88	4.12	3.73	4.71	3.37	4.22	3.67	4.38	4.15	4.05	3.86	3.68	3.57	3.76	3.83
1012	CSMF	2.13	2.21	2.98	2.92	2.39	3.28	2.34	2.27	3.25	2.83	3.72	2.26	2.92	2.41	3.09	2.86	2.98	2.76	2.89	2.85	3.00	2.78
5014	CSMF	1.63	1.52	2.46	2.34	1.84	2.78	1.88	2.00	2.79	2.36	3.16	1.75	2.31	1.86	2.47	2.25	2.42	2.21	2.47	2.48	2.61	2.27
5021	CSMF	1.38	1.16	2.19	2.03	1.56	2.51	1.64	1.86	2.53	2.11	2.84	1.49	2.01	1.59	2.16	1.95	2.11	1.92	2.24	2.28	2.39	2.00
6011	CSMF	0.80	0.35	1.52	1.30	0.86	1.85	1.09	1.49	1.89	1.52	2.07	0.95	1.33	1.01	1.44	1.27	1.41	1.28	1.70	1.79	1.84	1.37
6013	CSMF	0.62	0.10	1.29	1.06	0.64	1.63	0.91	1.35	1.67	1.32	1.81	0.79	1.13	0.84	1.23	1.07	1.19	1.08	1.51	1.62	1.65	1.17
6020	CSMF	0.39	-0.22	1.00	0.76	0.35	1.33	0.68	1.14	1.38	1.08	1.49	0.61	0.89	0.64	0.96	0.82	0.91	0.84	1.27	1.39	1.39	0.91
6021	CSMF	0.75	0.28	1.45	1.23	0.80	1.79	1.04	1.45	1.83	1.46	2.00	0.90	1.27	0.96	1.38	1.21	1.34	1.22	1.64	1.74	1.79	1.31
1009	CSMF	3.31	3.77	4.10	4.17	3.54	4.39	3.37	2.92	4.17	3.78	4.76	3.44	4.29	3.75	4.45	4.23	4.11	3.92	3.73	3.61	3.81	3.89
1010	CSMF	3.73	4.26	4.47	4.57	3.92	4.77	3.73	3.17	4.47	4.08	5.07	3.82	4.73	4.23	4.85	4.65	4.43	4.27	3.99	3.87	4.07	4.24
9101	COMF	1.87	1.77	2.70	2.58	2.08	3.01	2.10	2.17	3.01	2.58	3.39	1.99	2.56	2.11	2.72	2.50	2.66	2.45	2.68	2.68	2.81	2.50
9103	COMF	0.81	0.32	1.50	1.28	0.85	1.83	1.09	1.49	1.88	1.51	2.04	0.96	1.33	1.02	1.44	1.27	1.40	1.28	1.69	1.79	1.83	1.36
9105	COMF	0.32	-0.33	0.89	0.64	0.24	1.21	0.60	1.05	1.27	1.00	1.37	0.56	0.81	0.59	0.88	0.75	0.82	0.76	1.18	1.30	1.30	0.82
9107	COMF	0.16	-0.54	0.69	0.42	0.05	1.00	0.43	0.88	1.07	0.83	1.16	0.44	0.65	0.45	0.70	0.58	0.63	0.60	0.99	1.13	1.11	0.64
9102	COMF	1.61	1.42	2.42	2.28	1.79	2.74	1.86	2.02	2.76	2.33	3.08	1.73	2.26	1.83	2.41	2.20	2.36	2.16	2.45	2.48	2.59	2.23
9104	COMF	0.73	0.22	1.41	1.18	0.75	1.74	1.02	1.43	1.78	1.43	1.93	0.90	1.25	0.95	1.35	1.19	1.30	1.20	1.62	1.72	1.75	1.28
9106	COMF	0.68	0.15	1.35	1.12	0.69	1.68	0.97	1.39	1.72	1.38	1.87	0.85	1.19	0.91	1.29	1.13	1.25	1.14	1.57	1.67	1.70	1.22
9108	COMF	0.37	-0.26	0.96	0.71	0.31	1.28	0.66	1.11	1.34	1.05	1.44	0.60	0.87	0.63	0.93	0.80	0.88	0.82	1.24	1.36	1.36	0.88
9201	COMF	1.73	1.58	2.55	2.42	1.93	2.86	1.97	2.09	2.88	2.45	3.23	1.85	2.40	1.96	2.55	2.34	2.50	2.30	2.56	2.57	2.70	2.35
9203	COMF	1.11	0.74	1.86	1.66	1.21	2.19	1.39	1.71	2.22	1.83	2.44	1.24	1.67	1.32	1.80	1.61	1.76	1.61	1.99	2.06	2.14	1.69
9205	COMF	0.49	-0.10	1.12	0.87	0.46	1.44	0.78	1.23	1.49	1.18	1.61	0.70	0.99	0.74	1.07	0.93	1.02	0.95	1.37	1.49	1.50	1.02
9207	COMF	0.32	-0.33	0.90	0.64	0.25	1.21	0.60	1.05	1.27	1.00	1.37	0.56	0.81	0.59	0.88	0.75	0.82	0.76	1.18	1.30	1.30	0.82
9202	COMF	1.58	1.38	2.39	2.24	1.76	2.71	1.83	2.00	2.73	2.30	3.05	1.70	2.22	1.80	2.37	2.16	2.32	2.13	2.43	2.46	2.57	2.20
9204	COMF	1.15	0.79	1.90	1.71	1.26	2.23	1.42	1.73	2.27	1.87	2.50	1.28	1.72	1.36	1.85	1.66	1.81	1.65	2.03	2.10	2.18	1.74
9206	COMF	0.78	0.29	1.47	1.24	0.82	1.80	1.07	1.47	1.84	1.49	2.00	0.94	1.30	1.00	1.40	1.24	1.36	1.25	1.67	1.77	1.81	1.33
9208	COMF	0.32	-0.32	0.90	0.65	0.25	1.22	0.61	1.06	1.28	1.00	1.38	0.57	0.82	0.59	0.88	0.75	0.82	0.77	1.19	1.31	1.30	0.83
	Average	1.32	1.05	2.04	1.89	1.41	2.36	1.56	1.77	2.36	1.99	2.63	1.48	1.95	1.58	2.07	1.89	1.98	1.84	2.12	2.17	2.25	1.89

Table 21 : Risk score calculated for 150 year period using collapse risk, at medium hazard locations

PMFR																							
		Medium hazard locations																					
Archetype	Model type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Average
1003	CSMF	1.23	1.96	-0.19	0.73	1.16	-1.36	0.63	-1.33	-1.86	-0.61	-1.94	1.03	0.57	1.08	0.29	0.73	0.23	0.49	-1.61	-2.45	-2.28	-0.17
1011	CSMF	0.54	0.76	-0.55	0.10	0.50	-1.55	0.18	-1.12	-1.84	-0.80	-2.02	0.37	-0.14	0.31	-0.34	0.00	-0.24	-0.05	-1.56	-2.22	-2.10	-0.56
5013	CSMF	-0.04	0.11	-1.33	-0.64	-0.15	-2.40	-0.44	-1.77	-2.70	-1.56	-2.96	-0.25	-0.91	-0.34	-1.15	-0.75	-1.01	-0.78	-2.36	-3.03	-2.93	-1.30
5020	CSMF	-0.73	-0.68	-2.23	-1.52	-0.92	-3.39	-1.18	-2.51	-3.70	-2.44	-4.07	-0.97	-1.80	-1.11	-2.09	-1.63	-1.92	-1.63	-3.27	-3.95	-3.88	-2.17
1008	CSMF	1.14	1.95	-0.41	0.57	1.04	-1.64	0.48	-1.61	-2.19	-0.86	-2.28	0.92	0.41	0.98	0.11	0.59	0.02	0.31	-1.92	-2.79	-2.62	-0.37
1012	CSMF	0.28	0.70	-1.11	-0.30	0.21	-2.27	-0.22	-1.86	-2.64	-1.41	-2.81	0.07	-0.56	0.00	-0.80	-0.39	-0.71	-0.48	-2.32	-3.09	-2.95	-1.08
5014	CSMF	-0.15	0.06	-1.54	-0.80	-0.26	-2.68	-0.60	-2.04	-2.99	-1.79	-3.25	-0.38	-1.08	-0.48	-1.34	-0.91	-1.20	-0.95	-2.63	-3.35	-3.24	-1.51
5021	CSMF	-1.03	-0.87	-2.72	-1.91	-1.22	-3.98	-1.56	-3.09	-4.32	-2.95	-4.69	-1.31	-2.22	-1.46	-2.53	-2.03	-2.36	-2.04	-3.87	-4.62	-4.54	-2.63
6011	CSMF	0.86	0.52	0.60	0.81	0.81	0.15	0.89	0.55	0.00	0.53	-0.19	0.88	0.72	0.86	0.63	0.76	0.69	0.78	0.19	-0.13	-0.09	0.51
6013	CSMF	0.57	0.17	0.14	0.38	0.45	-0.38	0.55	0.17	-0.54	0.09	-0.79	0.59	0.31	0.55	0.18	0.37	0.25	0.39	-0.28	-0.62	-0.60	0.09
6020	CSMF	0.19	-0.26	-0.43	-0.16	-0.01	-1.03	0.13	-0.32	-1.20	-0.44	-1.52	0.24	-0.18	0.17	-0.35	-0.11	-0.29	-0.09	-0.86	-1.22	-1.23	-0.43
6021	CSMF	-0.21	-0.43	-1.29	-0.80	-0.41	-2.17	-0.46	-1.32	-2.41	-1.40	-2.79	-0.32	-0.97	-0.43	-1.20	-0.84	-1.07	-0.82	-2.02	-2.54	-2.51	-1.26
1009	CSMF	0.40	1.28	-1.50	-0.40	0.23	-2.91	-0.40	-2.73	-3.50	-1.99	-3.63	0.10	-0.59	0.15	-0.92	-0.38	-1.03	-0.67	-3.16	-4.12	-3.94	-1.42
1010	CSMF	0.04	1.04	-2.18	-0.96	-0.22	-3.72	-0.91	-3.54	-4.43	-2.75	-4.61	-0.34	-1.14	-0.23	-1.55	-0.91	-1.72	-1.28	-4.06	-5.09	-4.91	-2.07
9101	COMF	1.84	1.74	1.90	2.13	2.01	1.57	1.90	1.35	1.42	1.72	0.53	1.88	1.50	1.72	1.33	1.53	1.58	1.79	1.40	1.06	1.19	1.57
9103	COMF	1.12	0.68	1.31	1.31	1.10	1.20	1.28	1.29	1.13	1.28	1.07	1.21	1.30	1.23	1.30	1.30	1.31	1.31	1.17	1.03	1.06	1.19
9105	COMF	0.66	0.05	0.79	0.74	0.54	0.70	0.83	0.94	0.65	0.86	0.54	0.85	0.86	0.84	0.82	0.84	0.81	0.86	0.77	0.67	0.65	0.73
9107	COMF	0.46	-0.18	0.49	0.45	0.30	0.35	0.61	0.67	0.31	0.59	0.18	0.68	0.62	0.66	0.56	0.61	0.54	0.62	0.46	0.35	0.33	0.46
9102	COMF	1.75	1.55	1.93	2.08	1.89	1.70	1.86	1.51	1.58	1.79	0.79	1.80	1.55	1.68	1.41	1.56	1.64	1.79	1.55	1.29	1.40	1.62
9104	COMF	1.07	0.60	1.31	1.29	1.05	1.24	1.25	1.32	1.18	1.30	1.12	1.19	1.30	1.21	1.30	1.29	1.30	1.30	1.22	1.10	1.13	1.19
9106	COMF	0.74	0.31	0.60	0.71	0.65	0.31	0.80	0.63	0.20	0.58	0.05	0.81	0.69	0.79	0.62	0.72	0.66	0.73	0.35	0.13	0.15	0.53
9108	COMF	0.49	-0.06	0.34	0.40	0.34	0.07	0.57	0.47	-0.01	0.38	-0.19	0.63	0.47	0.59	0.39	0.49	0.40	0.51	0.18	-0.01	-0.02	0.31
9201	COMF	1.80	1.64	2.02	2.16	1.99	1.78	1.95	1.54	1.65	1.87	0.67	1.84	1.53	1.70	1.38	1.55	1.61	1.79	1.61	1.33	1.45	1.66
9203	COMF	1.27	0.98	1.32	1.43	1.29	1.09	1.36	1.16	0.99	1.24	0.95	1.31	1.35	1.33	1.33	1.37	1.37	1.37	1.04	0.81	0.88	1.20
9205	COMF	0.75	0.22	0.80	0.81	0.65	0.63	0.89	0.89	0.56	0.82	0.44	0.89	0.86	0.88	0.82	0.86	0.82	0.88	0.68	0.54	0.54	0.72
9207	COMF	0.53	-0.05	0.46	0.48	0.38	0.25	0.64	0.61	0.18	0.52	0.03	0.69	0.58	0.66	0.51	0.59	0.51	0.60	0.35	0.19	0.18	0.42
9202	COMF	1.74	1.53	2.02	2.11	1.91	1.84	1.91	1.62	1.73	1.89	0.82	1.79	1.55	1.68	1.42	1.56	1.64	1.79	1.69	1.44	1.55	1.68
9204	COMF	1.28	1.01	1.31	1.43	1.30	1.06	1.36	1.12	0.96	1.22	0.91	1.32	1.35	1.33	1.33	1.37	1.36	1.37	1.00	0.76	0.83	1.19
9206	COMF	0.79	0.40	0.62	0.75	0.71	0.30	0.83	0.60	0.19	0.58	0.04	0.83	0.71	0.81	0.64	0.74	0.68	0.75	0.33	0.09	0.12	0.55
9208	COMF	0.53	-0.05	0.46	0.48	0.38	0.24	0.64	0.60	0.17	0.51	0.01	0.69	0.58	0.66	0.51	0.58	0.51	0.60	0.34	0.18	0.17	0.42
	Average	0.66	0.56	0.10	0.46	0.59	-0.50	0.53	-0.21	-0.71	-0.04	-0.99	0.63	0.31	0.59	0.15	0.38	0.21	0.37	-0.52	-0.94	-0.87	0.04

Table 22 : PMFR values (τ = 50 years) at medium hazard locations

		PMFR																					
Archetype	Model type	Medium hazard locations																					Average
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
1003	CSMF	0.75	1.49	-0.67	0.25	0.68	-1.84	0.15	-1.81	-2.34	-1.09	-2.42	0.55	0.09	0.60	-0.18	0.26	-0.25	0.01	-2.09	-2.92	-2.75	-0.64
1011	CSMF	0.07	0.29	-1.03	-0.37	0.02	-2.02	-0.30	-1.60	-2.32	-1.28	-2.49	-0.11	-0.62	-0.17	-0.82	-0.48	-0.72	-0.53	-2.04	-2.70	-2.58	-1.04
5013	CSMF	-0.51	-0.36	-1.80	-1.12	-0.62	-2.88	-0.92	-2.25	-3.18	-2.03	-3.44	-0.72	-1.39	-0.82	-1.63	-1.23	-1.49	-1.26	-2.83	-3.51	-3.41	-1.78
5020	CSMF	-1.21	-1.16	-2.71	-2.00	-1.40	-3.87	-1.66	-2.98	-4.17	-2.91	-4.55	-1.45	-2.28	-1.58	-2.56	-2.10	-2.40	-2.11	-3.74	-4.43	-4.36	-2.65
1008	CSMF	0.67	1.47	-0.89	0.09	0.56	-2.12	0.00	-2.09	-2.67	-1.34	-2.76	0.44	-0.06	0.51	-0.37	0.11	-0.46	-0.17	-2.40	-3.27	-3.09	-0.85
1012	CSMF	-0.19	0.22	-1.59	-0.77	-0.26	-2.75	-0.69	-2.34	-3.12	-1.89	-3.28	-0.41	-1.04	-0.48	-1.28	-0.87	-1.19	-0.96	-2.79	-3.57	-3.43	-1.56
5014	CSMF	-0.63	-0.42	-2.02	-1.28	-0.74	-3.15	-1.08	-2.52	-3.47	-2.26	-3.73	-0.86	-1.56	-0.96	-1.81	-1.39	-1.68	-1.43	-3.11	-3.82	-3.72	-1.98
5021	CSMF	-1.51	-1.34	-3.19	-2.39	-1.70	-4.46	-2.04	-3.57	-4.80	-3.43	-5.17	-1.78	-2.70	-1.93	-3.01	-2.50	-2.84	-2.52	-4.35	-5.10	-5.01	-3.11
6011	CSMF	0.39	0.04	0.12	0.33	0.33	-0.33	0.41	0.07	-0.48	0.05	-0.67	0.40	0.24	0.38	0.15	0.29	0.21	0.30	-0.29	-0.61	-0.57	0.04
6013	CSMF	0.09	-0.31	-0.34	-0.10	-0.03	-0.85	0.08	-0.31	-1.01	-0.38	-1.27	0.12	-0.17	0.07	-0.29	-0.11	-0.23	-0.09	-0.76	-1.10	-1.08	-0.38
6020	CSMF	-0.28	-0.74	-0.90	-0.64	-0.48	-1.50	-0.34	-0.80	-1.67	-0.92	-1.99	-0.23	-0.66	-0.31	-0.83	-0.59	-0.76	-0.56	-1.34	-1.70	-1.71	-0.90
6021	CSMF	-0.69	-0.91	-1.76	-1.27	-0.89	-2.65	-0.94	-1.80	-2.89	-1.87	-3.26	-0.80	-1.44	-0.91	-1.67	-1.32	-1.55	-1.30	-2.50	-3.02	-2.99	-1.73
1009	CSMF	-0.08	0.80	-1.98	-0.88	-0.25	-3.38	-0.88	-3.21	-3.98	-2.46	-4.11	-0.38	-1.06	-0.33	-1.40	-0.85	-1.51	-1.15	-3.64	-4.60	-4.42	-1.89
1010	CSMF	-0.43	0.57	-2.66	-1.44	-0.69	-4.20	-1.39	-4.02	-4.91	-3.23	-5.08	-0.82	-1.62	-0.71	-2.03	-1.39	-2.20	-1.76	-4.54	-5.57	-5.39	-2.55
9101	COMF	1.37	1.26	1.42	1.65	1.53	1.09	1.42	0.87	0.94	1.24	0.06	1.40	1.02	1.24	0.86	1.05	1.11	1.31	0.92	0.59	0.71	1.10
9103	COMF	0.64	0.21	0.83	0.84	0.62	0.72	0.80	0.81	0.65	0.81	0.59	0.74	0.83	0.76	0.82	0.82	0.83	0.83	0.69	0.55	0.59	0.71
9105	COMF	0.18	-0.43	0.31	0.26	0.06	0.22	0.35	0.46	0.17	0.38	0.07	0.37	0.38	0.36	0.34	0.36	0.33	0.38	0.29	0.19	0.18	0.25
9107	COMF	-0.02	-0.66	0.02	-0.03	-0.18	-0.13	0.13	0.19	-0.17	0.11	-0.30	0.21	0.14	0.18	0.08	0.13	0.06	0.15	-0.01	-0.12	-0.15	-0.02
9102	COMF	1.27	1.07	1.45	1.60	1.42	1.22	1.38	1.04	1.11	1.31	0.31	1.32	1.07	1.20	0.94	1.08	1.16	1.31	1.08	0.81	0.92	1.15
9104	COMF	0.60	0.13	0.83	0.81	0.58	0.76	0.78	0.85	0.70	0.83	0.65	0.71	0.82	0.73	0.82	0.81	0.83	0.82	0.74	0.62	0.65	0.72
9106	COMF	0.26	-0.17	0.12	0.23	0.17	-0.17	0.33	0.15	-0.27	0.10	-0.42	0.33	0.21	0.31	0.14	0.24	0.18	0.25	-0.13	-0.35	-0.33	0.06
9108	COMF	0.01	-0.53	-0.14	-0.07	-0.14	-0.40	0.09	-0.01	-0.49	-0.10	-0.66	0.15	0.00	0.11	-0.09	0.01	-0.07	0.03	-0.30	-0.49	-0.50	-0.17
9201	COMF	1.32	1.16	1.55	1.68	1.51	1.30	1.47	1.07	1.17	1.39	0.20	1.36	1.05	1.22	0.90	1.07	1.14	1.32	1.14	0.85	0.97	1.18
9203	COMF	0.79	0.50	0.85	0.95	0.81	0.62	0.88	0.68	0.52	0.77	0.47	0.83	0.88	0.85	0.86	0.89	0.89	0.89	0.56	0.33	0.40	0.72
9205	COMF	0.27	-0.26	0.32	0.33	0.18	0.16	0.41	0.42	0.09	0.34	-0.04	0.41	0.38	0.40	0.34	0.38	0.35	0.40	0.21	0.06	0.06	0.25
9207	COMF	0.05	-0.53	-0.01	0.01	-0.10	-0.23	0.16	0.13	-0.30	0.04	-0.45	0.21	0.10	0.18	0.03	0.11	0.04	0.13	-0.13	-0.28	-0.30	-0.05
9202	COMF	1.26	1.05	1.55	1.64	1.43	1.36	1.44	1.15	1.25	1.42	0.34	1.31	1.07	1.20	0.94	1.08	1.16	1.31	1.21	0.97	1.07	1.20
9204	COMF	0.81	0.53	0.83	0.95	0.83	0.58	0.88	0.65	0.48	0.75	0.44	0.84	0.87	0.86	0.85	0.89	0.88	0.89	0.52	0.29	0.36	0.71
9206	COMF	0.31	-0.08	0.14	0.28	0.24	-0.18	0.35	0.13	-0.29	0.10	-0.43	0.35	0.23	0.34	0.16	0.26	0.20	0.28	-0.15	-0.39	-0.36	0.07
9208	COMF	0.05	-0.53	-0.02	0.01	-0.10	-0.23	0.16	0.12	-0.31	0.03	-0.46	0.21	0.10	0.18	0.03	0.11	0.03	0.12	-0.14	-0.30	-0.31	-0.06
	Average	0.19	0.08	-0.38	-0.02	0.11	-0.98	0.05	-0.68	-1.19	-0.52	-1.46	0.16	-0.17	0.12	-0.32	-0.10	-0.26	-0.10	-1.00	-1.42	-1.35	-0.44

Table 23 : PMFR values (τ = 150 years) at medium hazard locations

PMF_R Values of Medium Hazard Locations

For medium hazard locations and for a τ value of 50 years, the PMF_R value averaged over all the building models and locations is 0.04 ≈ 0. This indicates that in this case, the collapse probabilities conditioned on MCE_R shaking level and the collapse risks for a 50 year period are similar. However, this is not the case for medium hazard locations when τ = 150 years. A deterministic sensitivity study could be formed for medium hazard locations in an effort take this study further.

6. Deterministic Sensitivity Study

The main purpose for this sensitivity study is to check the parameter to which the PMF_R is most sensitive. The following parameters are considered – Median collapse capacity (θ), Logarithmic standard deviation of collapse capacity (β), slope of hazard curve (M), y-intercept of hazard curve (B) and risk coefficient (C_R). Low, baseline (or mean) and high values are determined for each of these parameters.

Low, mean and high values for median collapse capacity are calculated from Table 3. For logarithmic standard deviation of collapse capacity, they are set to be 0.5, 0.8 and 1.0 respectively. These values were chosen because Luco et. al. (2007) used β = 0.8, FEMA P-695 building models considered in this study had a low β = 0.5 and in FEMA P-695 the β values were as high as 0.95.

From a hazard curve, the mean annual exceedance frequencies are interpolated using double interpolation at 0.1g and 0.5g spectral response accelerations. The hazard curve between these values is assumed to be linear, as shown in Figure 6. Slope and y-intercept of the hazard curve is determined using these two points in the equation shown on page 47. This process is repeated for the hazard curves of all high hazard locations and the low, mean and high values of slope and y-intercept of hazard curve are determined.

For risk coefficient (C_R), the low, mean and high values are taken as 0.8, 0.9 and 1.17 respectively. These are the low, mean and high values obtained from risk coefficient maps of ASCE 7-10 (Figure 22-18 of ASCE 7-10).

After determining the required values of parameters, score, risk score and PMF_R values are calculated using similar procedures as mentioned in Chapter 4. To calculate the MCE_R spectral response acceleration value, the MCE value is first calculated using the following equation-

$$ln(y) = M.x + B$$

Where,

y = exceedance frequency (y = 1/2500 in this case since MCE is considered)

M = slope of hazard curve

B = y-intercept of hazard curve

x = shaking intensity (g) (MCE level-this is determined)

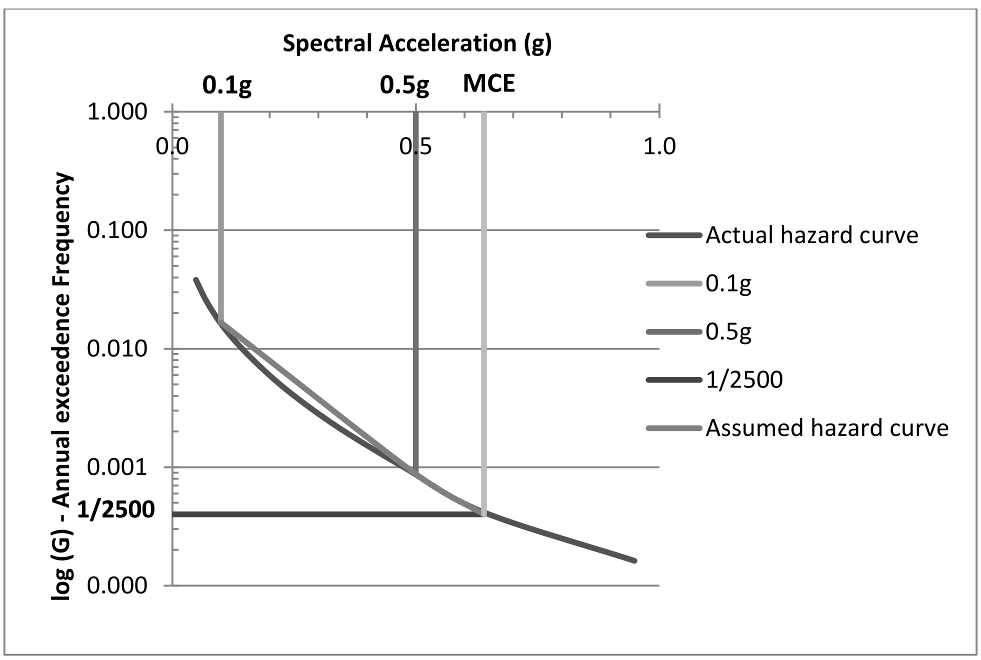

Figure 5: Linear approximation of hazard curve (sample representation)

As soon as we calculate MCE shaking intensity value (as shown in Figure 6), MCE_R value is calculated by multiplying MCE intensity value with the baseline risk coefficient value. Also, while calculating the risk integral, ground motion values for hazard curve are assumed and their respective mean annual frequencies are calculated using slope and y-intercept values.

Initially score, risk score and PMF_R values are calculated at the baseline (or mean) values of the parameters. When PMF_R at a low θ is to be calculated, except for θ, baseline values are taken for all other parameters. Similar method is used for all other cases.

For example,

PMF_R (at low θ) = f(low θ, baseline β, baseline M, baseline B and baseline C_R)

PMF_R (at high β) = f(baseline θ, high β, baseline M, baseline B and baseline C_R) etc.

After calculating the PMF_R values for all the cases, swing is calculated as absolute difference between PMF_R values calculated using low and high values of a parameter. A parameter with highest swing indicates that PMF_R is most sensitive to that parameter. A tornado diagram is a bar chart in which the low and high values of each parameter are plotted in the decreasing order of swing. The y-axis of this plot contains the PMF_R values and the x-axis represents the range of the values. A vertical line is drawn at the baseline PMF_R value. Figure 7 shows the tornado diagram for high hazard locations. Table 24 shows the parameters considered and their respective PMF_R values.

For example, Swing (in case of θ) = $|PMF_R$ (at high θ) – PMF_R (at low $\theta)|$

The following table shows the parameters considered and their respective PMF_R values. A tornado diagram is plotted with the decreasing order of swing. The y-axis intercepts the x-axis at the baseline PMF_R value, which is 0.395.

Parameter	Low	Mean	High	PMF_R (at low values)	PMF_R (at high values)	Swing
Theta - θ(g)	0.1652	1.3	3.09	0.105	0.483	0.378
Slope - M	-0.131	-0.048	-0.004	0.916	0.043	0.873
Y - intercept B (g)	0.003	0.026	0.067	1.228	-0.053	1.281
Beta - β (g)	0.5	0.8	1.0	0.564	0.311	0.254
Risk Coefficient (C_R)	0.8	0.9	1.17	0.279	0.626	0.346

Table 24 : Deterministic sensitivity study for high hazard locations - PMF_R and swing values

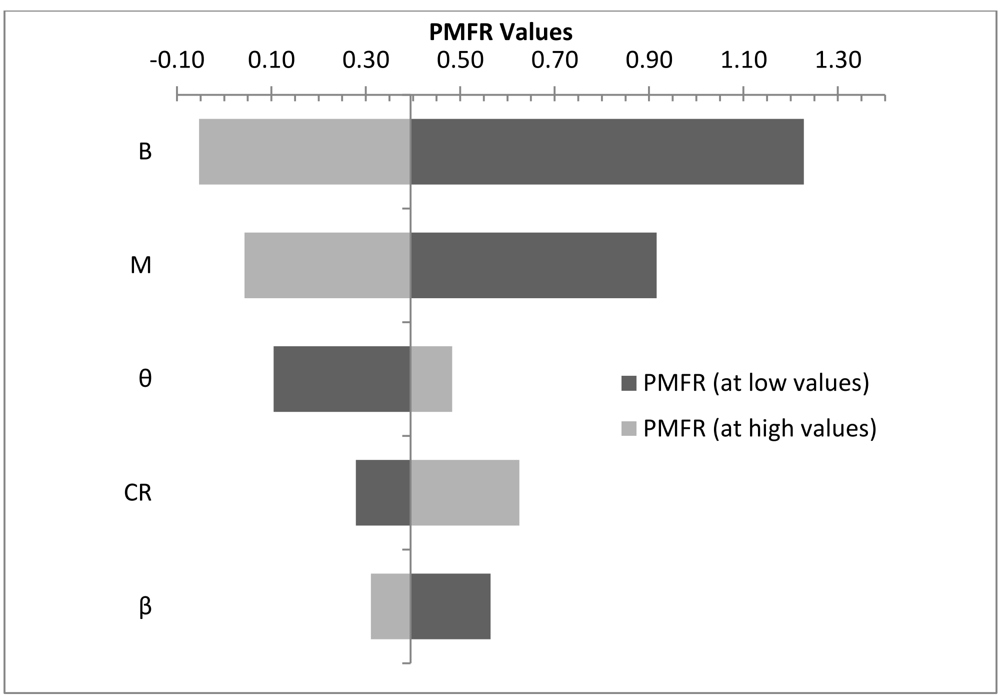

Figure 6: Tornado diagram for high hazard locations

According to the tornado diagram, PMF_R is very sensitive to slope and y-intercept of the hazard curve. I think that sensitivity to slope indicates that PMF_R is sensitive to the variation between intensity levels in a hazard curve and sensitivity to y-intercept indicates that PMF_R is sensitive to the low intensity earthquakes. The tornado also indicates that median collapse capacity of a building and its standard deviation are less sensitive to PMF_R. I think this indicates the PMF_R does not vary much depending on the type of building model used.

7. Conclusions

Bretl (2014) found that collapse probability given MCE_R shaking level is nearly equal to the 150 year collapse frequency of a building in case of high hazard locations. However, he did not arrive at a relationship for medium hazard locations.

In this study, when the risk score is calculated for 150 year period, the average PMF_R value for high hazard locations is $0.09 \approx 0$. This indicates that in this case, the collapse probabilities conditioned on MCE_R shaking level and the collapse risks for a 150 year period are similar. Hence, in FEMA 154, the score can be interpreted not just as the probability of collapse of a building given MCE_R shaking level, but also as the collapse risk over a period of 150 years. This result is similar to the result from Bretl's (2014) study.

Similarly, when the risk score is calculated for a 50 year period, the average PMF_R value for medium hazard locations is $0.04 \approx 0$. This indicates that in this case, the collapse probabilities conditioned on MCE_R shaking level and the collapse risks for a 50 year period are similar. Hence, in FEMA 154, the score can be interpreted not just as the probability of collapse of a building given MCE_R shaking level, but also as the collapse risk over a period of 50 years.

However, PMF_R values calculated using 50 year risk score for high hazard locations and 150 year risk score values for medium hazard locations did not yield any definite results. Also, even in the cases mentioned in the above two paragraphs, the PMF_R values are not near zero for several location-building combinations. Hence, a deterministic sensitivity study is performed for high hazard locations to check for an input parameter to which the PMF_R was most sensitive.

The deterministic sensitivity study showed that PMF_R is most sensitive to the slope and y-intercept values of the hazard curves. Further study could be done in this area to know more about how the hazard curves affect PMF_R. A similar sensitivity study could be performed to medium hazard locations to check for variations between the sensitivity studies, if any.

In this study the risk integral is solved using a numerical integral. Since the PMF_R is most sensitive to hazard curves, further study could be done to calculate the risk integral as a closed form of integral than by calculating using a numerical integration procedure.

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