
SP3-RiskModel SEISMIC RISK ASSESSMENT REPORT

Full Detailed Report



Report Generated for:

1 Palm Drive, Stanford, CA, 94305

Latitude: 37.4275°

Longitude: -122.17°

Report Generated by:

The SP3-RiskModel Software of the
Seismic Performance Prediction Program (SP3)

July 12, 2018

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1 EXECUTIVE SUMMARY

Risk Model Inputs

Primary		Secondary	
Model Name:	Stanford - 8 Story Steel SMF	Site Class:	–
Client Name:	Sample Client	Risk Category:	–
Building Type:	Steel Moment Frame Perimeter	Cost per Square Foot:	–
Building Category:	Existing	Total Square Feet	–
Year of Construction:	2018	Aspect Ratio	–
Number of Stories:	8	First Story Height (ft)	–
Occupancy:	Commercial Office	Upper Story Heights (ft)	–
<i>Site</i>		Seismic Importance Factor, I_e :	–
Street:	1 Palm Drive	Drift Limit:	–
City:	Stanford	Component Importance Factor, I_p :	–
State:	CA	Percent of Building Glazed:	–
Zip:	94305	<i>Structural Retrofit</i>	
Latitude:	37.428°	Year:	–
Longitude:	-122.17°	Percent Code Compliance:	–
		<i>Non-Structural Retrofit</i>	
		Year:	–
		Percent Code Compliance:	–

Expected Loss

Table 1. Expected loss in percent of total building value.

Shaking Intensity	Return Period	SEL (%)	SUL (%)
50% in 50 years	72 Years	3.23	6.42
10% in 50 years	475 Years	12.6	22.0
2% in 50 years	2475 Years	59.1	94.3

2 BASIS OF ANALYSIS

This analysis is based on the SP3-RiskModel of the Seismic Performance Prediction Program (SP3) software platform. The underlying analysis methods are based on the FEMA P-58 analytical method, which is a transparent and well documented method that was developed through a 15 year project, which leveraged the previous decades of academic research, funded by a \$16 million investment by the Federal Emergency Management Agency (FEMA). In contrast to many risk assessment methods based on judgment and past earthquake experience, the FEMA P-58 and SP3 analysis are based on engineering-oriented risk evaluation methods.

3 DOCUMENTATION OF SITE AND BUILDING INPUT DATA

Client Name: Sample Client

3.1 Site Information

Address: 1 Palm Drive, Stanford, CA, 94305

Latitude: 37.4275°

Longitude: -122.17°

3.2 Building Information

Material Type:	Steel
Building Type:	Steel Moment Frame Perimeter
Design Year:	2017
Number of Stories:	8
Total Building Square Footage:	80,000
Occupancy Type:	Commercial Office
Total Building Value:	\$19,346,046

4 SITE HAZARD INFORMATION

This section presents the site’s seismic hazard information. The Vs30 value is the shear wave velocity in the soil at a depth of 30 meters. This value and the associated site class are presented in Table 2.

Table 2. Site soil information.

Vs30 (m/s)	320.0
Site Class	D

Table 3 and Figure 1 present the spectral acceleration information for this site. The spectral acceleration is a measure of how much force the building will attract in an earthquake. This amount of force is dependent on the intensity of the ground shaking (e.g. 10% in 50 Years), as well as a dynamic property of the building known as the “fundamental period”. Shorter buildings tend to have smaller fundamental periods and taller buildings tend to have larger fundamental periods. As indicated by Figure 1, smaller fundamental periods (with the exception of very short fundamental periods) will attract more force in an earthquake.

Table 3. Spectral acceleration values.

Shaking Intensity	PGA (g)	$S_a(0.2s)$ (g)	$S_a(1.0s)$ (g)	$S_a(1.5s)$ (g)
50% in 50 years	0.21	0.49	0.20	0.14
DBE	0.47	1.04	0.53	0.40
10% in 50 years	0.53	1.17	0.62	0.47
MCE	0.63	1.39	0.78	0.60
2% in 50 years	0.93	2.06	1.28	1.01

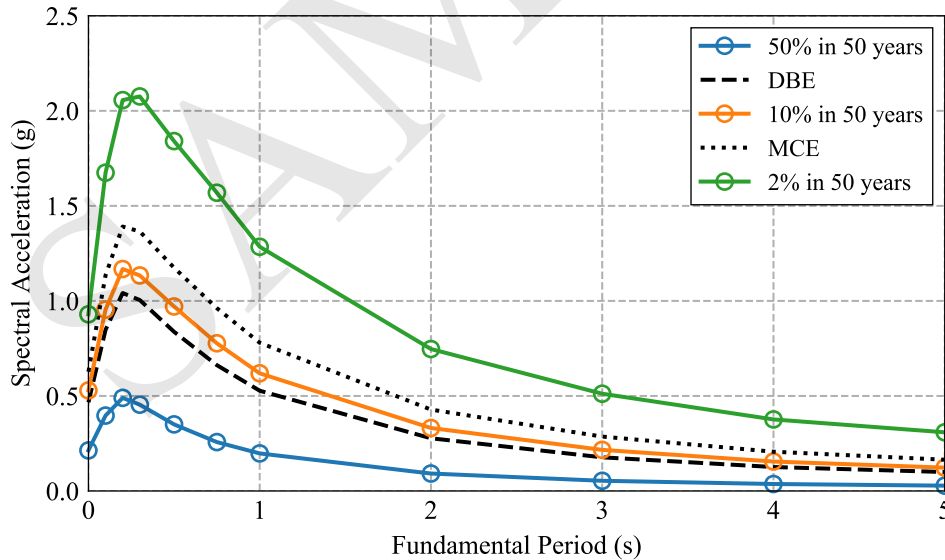


Figure 1. Hazard curves for this site.

5 BUILDING DESIGN SUMMARY FROM THE SP3 BUILDING CODE DESIGN DATABASE

5.1 Code Design Parameters

The seismic design parameters used to compute the seismic base shear coefficients for this building are presented in Table 4. These parameters are specific to the ASCE/SEI 7-2010.

Table 4. Code design parameters for 2010 ASCE/SEI 7

(a) Structural system specific parameters		(b) Site specific parameters	
Parameter	Value	Parameter	Value
I_e	1.0	S_s	1.736
C_t	0.028	S_1	0.785
C_d	5.5	S_{ds}	1.157
x	0.8	S_{d1}	0.785
R	8.0	SDC	E
Ω_0	3.0	C_u	1.4

5.2 Structural Properties

This section summarizes the main structural properties of the building in each direction. These structural properties are the basis of the SP3 Structural Response Prediction Engine.

Table 5. Structural properties table

Parameter	Direction 1	Direction 2
Length (ft)	100	100
Detailing Level	special	special
Expected Drift, (%)	1.90	1.90
Seismic Design Base Shear Ratio, C_s	0.061	0.061
Total Base Shear Ratio, v_y	0.17	0.17
$T_{1,design}$ (s)	2.03	2.03
T_1 with wind (s)	2.02	2.02
T_1 with over stiffness (s)	1.77	1.77
T_1 with gravity system (s)	1.67	1.67
$T_{1,actual}$ (s)	1.50	1.50

6 STRUCTURAL RESPONSE PREDICTIONS FROM THE SP3 STRUCTURAL RESPONSE PREDICTION ENGINE

The SP3 Response Engine predicts the structural responses (typically providing 100 ground motions per intensity level); this is done by using a combination of three-mode elastic modal analysis, coupled with both elastic and inelastic response modifiers mined from our large Structural Responses Database (with over 4,000,000 response simulations, and growing). These response predictions track all of the important statistical information in the responses (mean, variability, and correlations); this enables a statistically robust vulnerability curve at the end of the risk assessment process.

6.1 Peak Story Drift

Interstory drift is an important metric for both structural and non-structural components in the building. It is a measure of how much ceiling of a given story moves relative to the floor, commonly normalized to the height of the story. The greater the interstory drift, the greater the damage to the components on that level. Typical components that are damaged from interstory drift are structural components (beams and columns), gypsum partition walls, and exterior cladding and glazing.

Table 6. Peak Story Drift demands are the same in both directions.

Story	50% in 50 years	DBE	10% in 50 years	MCE	2% in 50 years
8	0.27	0.60	0.68	0.79	1.08
7	0.36	0.82	0.93	1.11	1.61
6	0.41	0.94	1.07	1.28	1.89
5	0.44	1.00	1.14	1.37	2.03
4	0.45	1.08	1.24	1.53	2.41
3	0.47	1.17	1.36	1.72	2.88
2	0.48	1.33	1.59	2.10	3.88
1	0.46	1.26	1.51	2.00	3.71

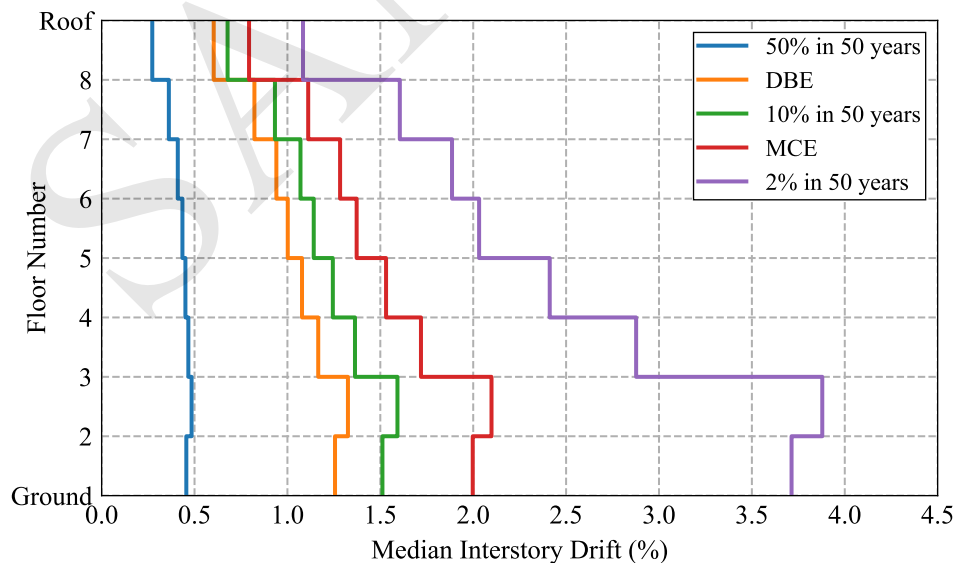


Figure 2. Peak Story Drift demands are the same in both directions.

6.2 Peak Floor Acceleration

Acceleration is an important metric for non-structural components in the building. Components such as piping, HVAC, and electrical switchgear are sensitive to the floor accelerations. High accelerations will typically damage a component itself or cause the component’s anchorage to fail, both of which may require repair or replacement of the component.

Table 7. Peak Floor Acceleration demands are the same in both directions.

Floor	50% in 50 years	DBE	10% in 50 years	MCE	2% in 50 years
Roof	0.45	0.52	0.53	0.55	0.57
8	0.35	0.43	0.44	0.45	0.48
7	0.32	0.41	0.42	0.45	0.50
6	0.29	0.39	0.41	0.44	0.52
5	0.27	0.39	0.42	0.46	0.56
4	0.26	0.40	0.43	0.48	0.61
3	0.24	0.42	0.46	0.52	0.70
2	0.22	0.42	0.47	0.54	0.76
Ground	0.21	0.47	0.53	0.63	0.93

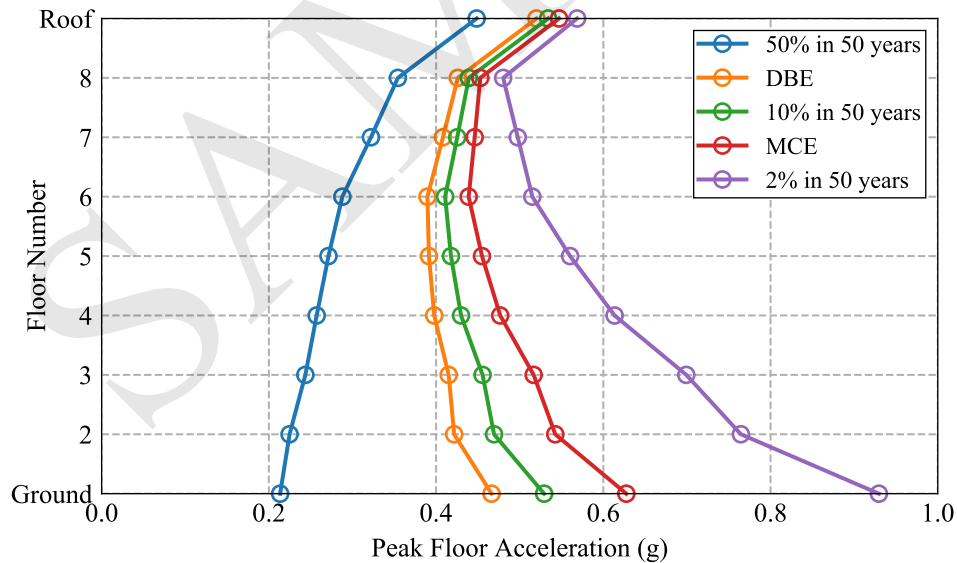


Figure 3. Peak Floor Acceleration demands are the same in both directions.

6.3 Residual Story Drift

Residual drift is a measure of how much the building is “leaning over” after the earthquake shaking is finished. For structural systems that do not self-center, the building may be leaning over so much that it warrants demolition. A residual drift of 2% would indicate that the story is laterally displaced 2% of its height, which equates to about 3.6 inches for a 15 foot tall story. This can be visually unsettling and prohibitively expensive (or even impossible) to “straighten” the building and repair the structural damage. Due to this, the building owner will decide to completely demolish and rebuild the building if the residual drift is too high.

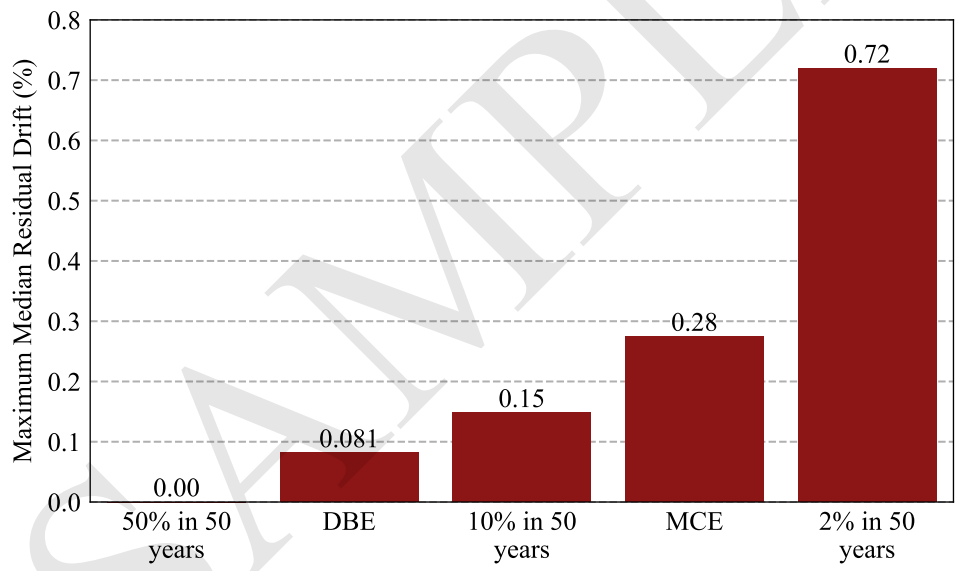


Figure 4. Residual Story Drift demands are the same in both directions.

7 REPAIR COSTS - BY LEVEL OF GROUND MOTION

7.1 Mean and 90th Percentile Repair Costs (SEL and SUL)

The different metrics for repair cost are as follows:

- **Mean (SEL):** (“Scenario Expected Loss”) the average repair cost of the building repair/replacement.
- **Median:** there is a 50% probability that the repair cost will not exceed this value.
- **Fitted SUL:** Fitted value of “Scenario Upper Loss”.
- **Counted 90th Percentile:** there is a 90% probability that the repair cost will not exceed this value.

Table 8. Expected loss normalized by building cost.

IM Level	PGA (g)	Mean (SEL) (%)	Fitted SUL (%)	Median (%)	Counted 90 th Percentile (%)
50% in 50 years	0.21	3.23	6.42	2.87	6.42
DBE	0.47	9.87	17.8	8.45	17.8
10% in 50 years	0.53	12.6	22.0	10.8	22.0
MCE	0.63	20.4	36.1	15.4	36.1
2% in 50 years	0.93	59.1	94.3	47.2	100

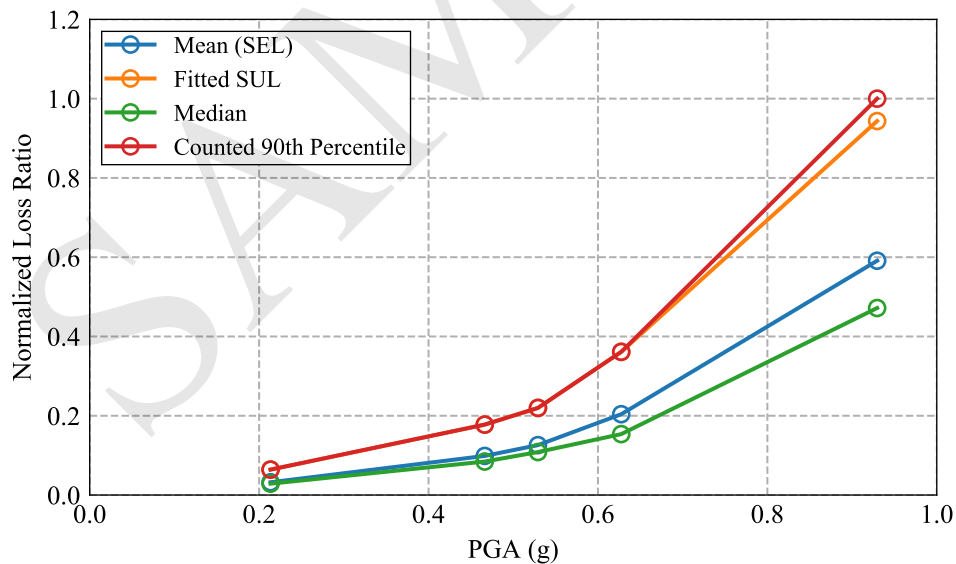


Figure 5. Loss metrics across all intensity levels analyzed.

8 REPAIR COST BREAKDOWN BY BUILDING COMPONENTS

8.1 Total Loss Breakdown

Repair costs are binned into eight categories as follows:

- **Collapse:** repair cost associated with building demolition and replacement following a collapse.
- **Residual:** repair cost associated with building demolition and replacement following unacceptable residual drifts.
- **Structural:** repair cost associated with components of the lateral force resisting system or gravity system (e.g. beam column connections, link beams, shear wall, shear tabs, etc.).
- **Partitions:** repair cost associated with partition wall components (e.g. wood or metal stud gypsum full height partitions).
- **Exterior:** repair cost associated with components placed on the exterior of the building (e.g. cladding, glazing, etc.).
- **Interior:** repair cost associated with non-structural components on the interior of the building (e.g. raised access floors, ceilings, lighting).
- **Plumbing:** repair cost associated with plumbing components (e.g. water piping and bracing, sanitary piping, etc.).
- **Other:** repair costs to components not included in the categories above (e.g. elevators, user defined components, fire protection components).

Display of these categories does not necessarily indicate that components of the same category are included in the building model, a category repair cost of zero may indicate no damage to existing components or no inclusion of these components.

Table 9. Expected mean loss per component group (in percent).

IM Level	Total	Residual	Collapse	Structural	Exterior	Other	Interior	Partition	HVAC
50% in 50 years	3.23	0.00	6.63e-5	0.040	0.78	1.17	0.18	0.14	0.92
DBE	9.87	0.00	0.079	1.89	3.34	1.98	0.54	0.83	1.15
10% in 50 years	12.6	0.29	0.20	3.12	4.16	2.03	0.63	1.02	1.20
MCE	20.4	3.29	0.63	5.82	5.43	2.15	0.71	1.29	1.13
2% in 50 years	59.1	31.7	5.04	11.6	6.06	1.73	0.91	1.24	0.84

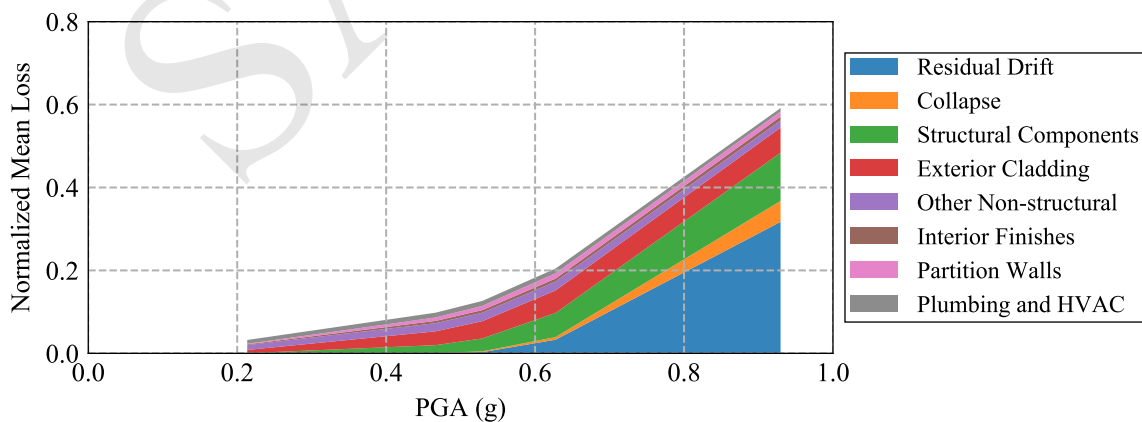


Figure 6. Contribution of building components to mean loss ratio.

8.2 Most Damaged Components

Table 10. Most damaged Structural components at each intensity level.

Intensity	Component	Damage State	Expected Repair Cost
50% in 50 years	B1035.011	1	\$4,784
DBE	B1035.011	1	\$241,318
10% in 50 years	B1035.011	1	\$392,834
MCE	B1035.011	1	\$722,756
2% in 50 years	B1035.011	3	\$1,326,498

Table 11. Most damaged Non-Structural components at each intensity level.

Intensity	Component	Damage State	Expected Repair Cost
50% in 50 years	D5012.0231	1	\$138,744
DBE	B2022.002	2	\$362,237
10% in 50 years	B2022.002	2	\$471,598
MCE	B2022.002	2	\$661,136
2% in 50 years	B2022.002	2	\$769,981

Details of the most damaged components and their damage states:

- **B1035.011:** Post-Northridge RBS connection with welded web, beams both sides of column, beam depth $\leq W27$
 - DS 1: Local beam flange and web buckling.
 - DS 3: Low-cycle fatigue fracture in buckled region of RBS.
- **B2022.002:** Curtain Walls - Generic Midrise Stick-Built Curtain wall, Config: Insulating Glass Units (dual pane), Lamination: Unknown, Glass Type: Unknown, Details: Aspect ratio = 6:5, Other details Unknown
 - DS 2: Glass falls from frame.
- **D5012.0231:** Low Voltage Switchgear - Capacity: 1200 to 2000 Amp - Equipment that is either hard anchored or is vibration isolated with seismic snubbers/restraints - Combined anchorage/isolator & equipment fragility
 - DS 1: Anchorage failure.

9 REPAIR COSTS - ANNUALIZED

The following is a summary of the expected annual loss for this building.

Table 12. Annualized loss information.

Total Annualized Loss	\$34,569
Annual Probability of Collapse	0.00010
Annual Probability of Unrepairable Residual Drift	0.00035
Annual Repair Time (serial days)	1.22
Annual Repair Time (parallel days)	0.60

Table 13. Breakdown of total annualized loss by component type.

Component Type	Expected Annual Loss
Exterior Cladding	\$7,830
Residual Drift	\$6,825
Other Non-structural	\$5,633
Structural Components	\$5,395
Plumbing and HVAC	\$3,754
Collapse	\$1,974
Partition Walls	\$1,784
Interior Finishes	\$1,323
Total	\$34,569

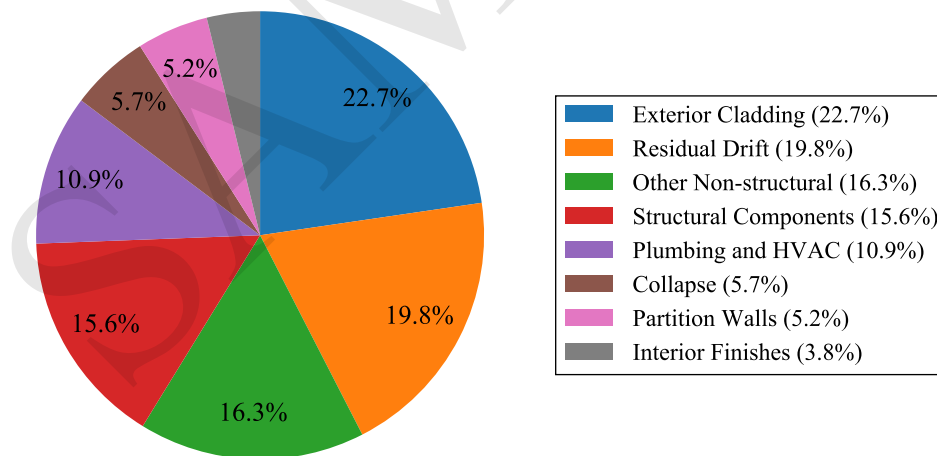


Figure 7. Annualized loss breakdown.

10 REPAIR TIME AND BUILDING CLOSURE TIME

The different methods of calculating recovery time from the FEMA P58 methodology are:

- Series: Repair activities are limited to one floor at a time
- Parallel: All floors are repaired at the same time

The different repair times as part of the REDi™ Rating System are as follows:

- Re-Occupancy: time after which the building is deemed safe enough to be used for shelter
- Functional Recovery: time required to establish re-occupancy and regain the facility’s primary function
- Full Recovery: time required to restore the building to its original pre-earthquake condition

Note: these values do not include impedance factors.

Table 14. Mean repair time (in days).

IM Level	FEMA P58 Parallel	FEMA P58 Series	REDi™ Re-Occupancy	REDi™ Functional Recovery	REDi™ Full Recovery
50% in 50 years	8.85	18.4	9.73	15.0	15.5
DBE	24.5	72.6	23.9	35.2	36.9
10% in 50 years	31.9	95.5	34.3	45.8	47.4
MCE	62.3	155	70.5	82.1	83.9
2% in 50 years	270	408	295	303	303

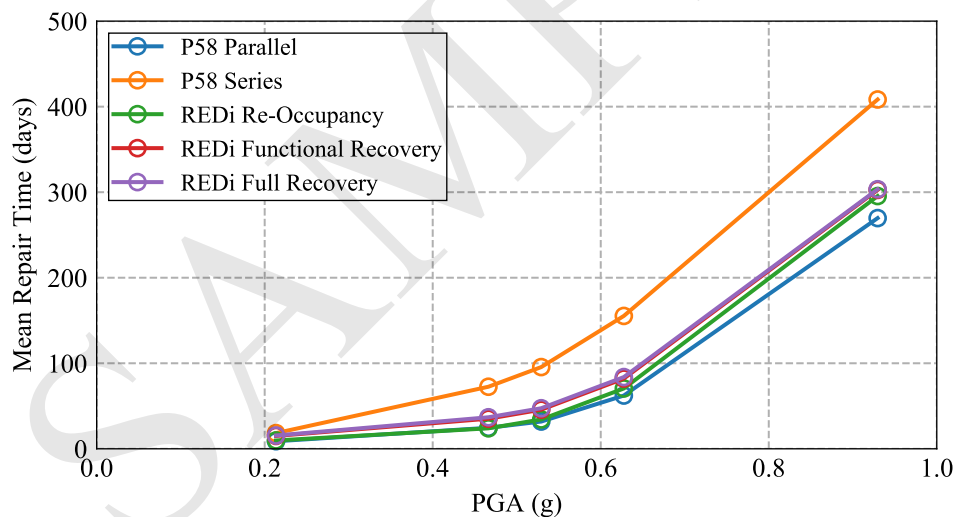


Figure 8. Mean repair time.

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