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Comparison of FEMA P-58 with Other Building Seismic Risk Assessment Methods

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ABSTRACT

Results from various seismic risk assessment methods are compared for three types of buildings. This study examines results from the FEMA P-58 method and compares the results with two other traditional methods for seismic due-diligence risk assessments (Thiel Zsutty method and ATC-13 method). The objectives of this study are to highlight key differences and similarities between FEMA P-58 (a building-specific-based loss assessment method) and other building-classification-based loss assessment methods.

For the buildings investigated: (a) the FEMA P-58 method gives similar results to building-classification-based methods in high-seismic zones on average, but lower loss results on average in lower seismic zones, and (b) the FEMA P-58 method results vary more between buildings, because it quantifies the effects of building-specific (and site-specific) attributes to provide a more detailed risk assessment for the individual building (in contrast to giving results for a building class and adding modifiers).

Introduction

There are a variety of methods employed in estimating seismic loss, leading to considerable variability between loss analyses performed by different professionals. This study examines three of the more common methods: T-Z (Thiel and Zsutty 1987), ATC-13 (ATC 1985), and FEMA P-58 (FEMA 2018). The FEMA P-58 method is implemented with SP3-batch (SP3 2022) using basic building information only; nonetheless, a large number of building-specific characteristics are still captured through the automation features of SP3 based on building height, location, historical building code requirements, and construction practices.

Using these risk assessment methodologies, the Scenario Expected Loss (SEL, i.e. the expected loss for a 475-year event) is computed for many different buildings with varying occupancy types, structural systems, and locations. The results are compared and the differences in the methods are discussed.

Building Model and Site

The buildings modeled in this study are located in high, moderate, and low seismic zones. The 2014 USGS database with 2018 updates to California locations is used to determine seismicity based on site location (latitude and longitude) and average shear wave velocity to 30 meters below the ground surface (Vs30).

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Building sites, seismicity, and corresponding site class examined in this study are summarized in Table 1. The test buildings, ranging in number of stories, structural system type, occupancy type, building construction year, and other miscellaneous attributes are summarized in Table 2.

Table 1 – Building Site Information

City	Seismicity Level	State	Latitude (deg)	Longitude (deg)	PGA Vs30 = 270 m/s	PGA Vs30 = 760 m/s
Los Angeles	High	CA	34.05	-118.25	0.50	0.44
Santa Barbara	High	CA	34.45	-119.70	0.47	0.41
San Jose	High	CA	37.33	-121.89	0.62	0.55
San Francisco	High	CA	37.75	-122.40	0.51	0.44
Oakland	High	CA	37.80	-122.27	0.57	0.51
Seattle	Moderate	WA	47.64	-122.38	0.40	0.32
Reno	Moderate	NV	39.53	-119.81	0.43	0.36
San Diego	Moderate	CA	32.72	-117.16	0.31	0.25
Long Beach	Moderate	CA	33.77	-118.19	0.42	0.34
Sacramento	Low	CA	38.60	-121.50	0.20	0.14
Chico	Low	CA	39.73	-121.84	0.24	0.18
Las Vegas	Low	NV	36.17	-115.14	0.13	0.09
Salt Lake City	Low	UT	40.76	-111.89	--	0.23
Memphis	Low	TN	35.15	-90.05	--	0.20
St Louis	Low	MI	38.60	-90.20	--	0.10
New York	Low	NY	40.75	-74.00	--	0.04

Table 2 - Building Information and Structural Description

Building Structural System	Occupancy Type	Building Construction Year	Story Heights	Aspect Ratio	Building Square Footage	Number of Building Evaluations
Wood Light Frame (WLF)	Multi-Unit Residential	1945, 1963, 1978, 1990, 1999, 2002, 2010, 2015	1, 3, 5	1	--	288
Pre-Northridge Steel Moment Frame (PNMF)	Commercial Office	1963, 1978, 1990	4, 8, 12, 20, 40	1,2	--	360
Tilt-Up	Warehouse	1945, 1963, 1978, 1990, 2002, 2010, 2015	1	1, 2, 3	40000, 80000, 16000, 320000, 480000	980

Comparison of Methods for each Building Construction Type

Tables 3 & 4 summarize loss prediction results (SEL) for the FEMA P-58, ATC-13 and T-Z methods. The T-Z and ATC-13 methods have been implemented based on appropriate structural description, corresponding ATC designation, occupancy type, number of stories, hazard level, and site class. Note that the FEMA P-58 loss prediction results omit any contributions from collapse or residual drift. The mean and coefficient of variation (COV; i.e., standard deviation divided by the mean) are shown for groups of buildings with the same building class and similar site characteristics. Each individual SEL result is compared for each building construction type in Figures 1-4. The figures provide insight into the increased variance in results provided by the FEMA P-58 method.

Table 3 – Seismic Risk Assessment Results

Building Construction Type	Seismicity Level	Site Class	Number of Building Evaluations	SEL			
				FEMA P-58		T-Z	
				Mean	COV	Mean	COV
WLF: Multi-Unit Residential	High	D	120	0.13	0.24	0.11	0.07
	High	B/C	120	0.09	0.24	0.07	0.07
	Moderate	D	96	0.09	0.31	0.09	0.09
	Low	B/C	168	0.02	0.78	0.03	0.30
PNMF: Commercial Office	High	D	150	0.21	0.40	0.21	0.07
	High	B/C	150	0.07	0.50	0.14	0.07
	Moderate	D	120	0.12	0.54	0.17	0.09
	Low	B/C	210	0.07	0.74	0.12	0.28

Table 4 – Seismic Risk Assessment Results for Tilt-Up: Warehouse

Building Construction Years	Seismicity Level	Site Class	Number of Building Evaluations	SEL			
				FEMA P-58		ATC-13	
				Mean	COV	Mean	COV
1945, 1963	Low, Moderate, & High	B/C & D	280	0.09	0.62	0.08	0.56
1978, 1990			280	0.07	0.72	0.08	0.56
2002, 2010, 2015			420	0.04	0.88	0.08	0.56

In Figure 1 the FEMA P-58 method shows a large variance in SEL, not captured by the T-Z method, mostly because the FEMA P-58 method captures the effect of building height. Figure 1 also shows that the FEMA P-58 method provides lower losses than the T-Z method for wood light-frame buildings in lower seismic zones; wood light-frame buildings have significant strength contributions from non-seismic systems (e.g., interior and exterior wall materials), so the base shear strength is similar whether designed for low or high-seismic zones.

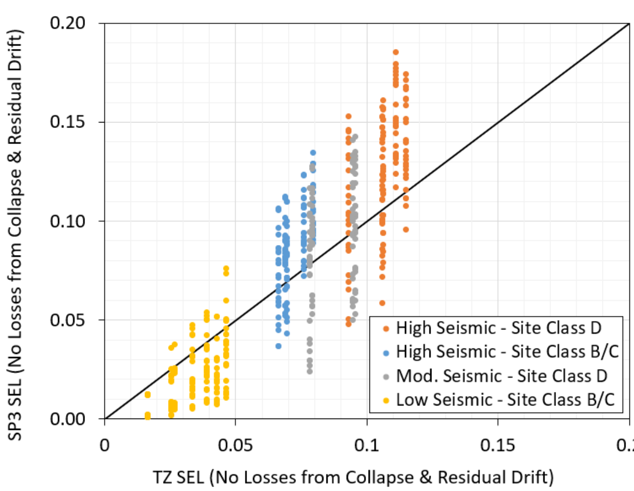

Figure 1. FEMA P-58 vs. T-Z: WLF

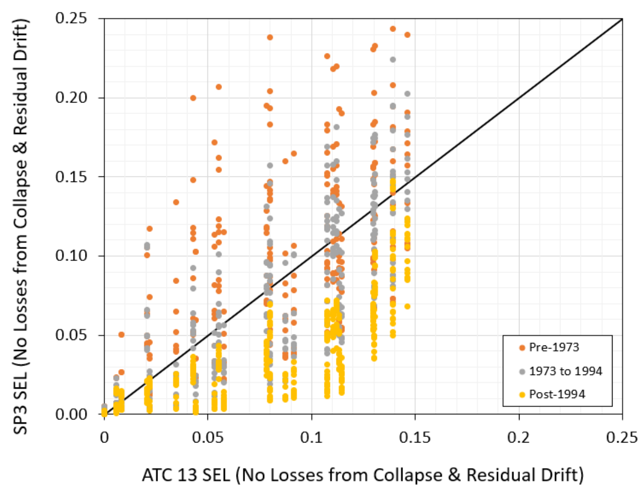

Figure 2. FEMA P-58 vs. ATC-13: Tilt-Up

In Figure 2 the FEMA P-58 method shows a large variance in SEL, not seen with the ATC-13 method, because of sensitivity to building attributes such as plan size, aspect ratio, and specific building code design requirements. Of significant importance, the FEMA P-58 method directly captures the out-of-plane anchorage requirements using age-specific design requirements.

In Figure 3 the FEMA P-58 method shows a large variance in SEL, not captured by the T-Z method, mostly because the FEMA P-58 method captures the effect of building height.T-Z Figure 3 also shows that the FEMA P-58 method provides lower losses than the T-Z method for pre-Northridge moment frame buildings in lower seismic zones.

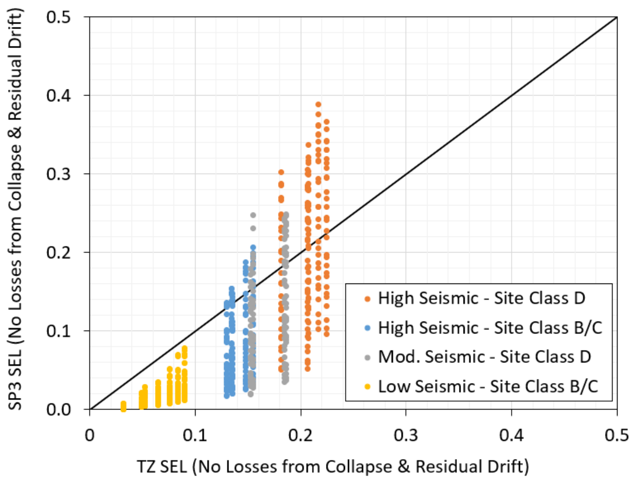

Figure 3. FEMA P-58 vs. T-Z: PNMF

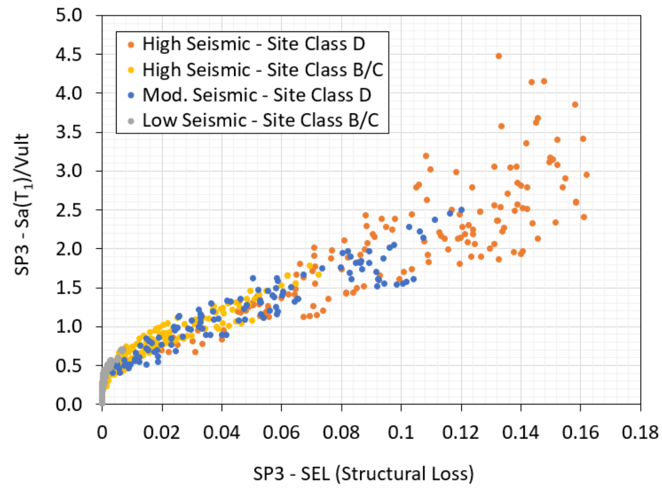

Figure 4. $Sa(T_1)/V_{ult}$ vs. PNMF Structural Loss (SP3)

In Figure 4 the PNMF structural loss (a portion of the total SEL) is compared to $Sa(T_1)/V_{ult}$ (i.e., the ratio of shaking intensity to building base shear ultimate strength). $Sa(T_1)/V_{ult}$ is strongly correlated with structural loss in the FEMA P-58 method; SP3 captures this affect based on design requirements for building base shear strength and the site-specific demand based on the expected fundamental period of the building, rather than PGA.

Conclusions

For the buildings investigated in this study, it is observed that (a) the FEMA P-58 method predicts similar loss results to T-Z and ATC-13 methods on average in high-seismic zones, (b) the FEMA P-58 method predicts lower loss results in lower seismic zones, and (c) the FEMA P-58 method results vary more between buildings of a specific class because the method quantifies the effects of building-specific (and site-specific) attributes. While traditional risk assessment methods are good for quick predictions of seismic losses for general building classes, each method is based on its own set of historical data and/or engineering judgement and does not have the ability to quantify certain building-specific or site-specific attributes.

One of the objectives of FEMA when initiating the FEMA P-58 project in 2001 was to create a state-of-the-art seismic risk assessment method that is based on an engineering-prediction-approach rather than being based on historical data and judgment. After a 10-year effort, this FEMA P-58 evaluation method was released and now provides this state-of-the-art building-specific risk assessment approach, supported by a comprehensive damage and loss database including information for over 1,000 structural and non-structural building components. The FEMA P-58 method can now be used to provide a comprehensive and credible basis for seismic risk assessment evaluations.

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