A Comparison of Losses Calculated Using HAZUS® Damage Estimates with Degenkolb Damage Estimates with ST-RISK® for Sites in San Francisco and Los Angeles

ST-RISK® 4.5 includes an implementation of HAZUS damage estimates, in addition to the previously implemented ST-RISK® damage methodology (which we will refer to here as Degenkolb damage estimates). These two methods of estimating seismic damage use different approaches to characterizing seismic intensity, base class build quality, and economic losses. The two methods are ultimately based on different sets of empirical data and experience on building losses due to seismic events. Consequently, as should be expected, they yield different results for any particular building analysis. However, it may be surprising just how much the damage estimates can vary under some circumstances. This comparison demonstrates the general pattern of how damage estimates vary between the two methods by investigating sites in downtown San Francisco and Los Angeles. It considers a 13 story high office building, of typical construction for its age. The comparison examines the sensitivity of the 475 year PML value to building age and soil conditions for three different building classes; concrete moment frame, concrete shear wall, and steel moment frame.

The following figure shows results in San Francisco for a building constructed using a concrete moment frame, as the ratio of PML calculated using the two methods (HAZUS PML divided by Degenkolb PML):

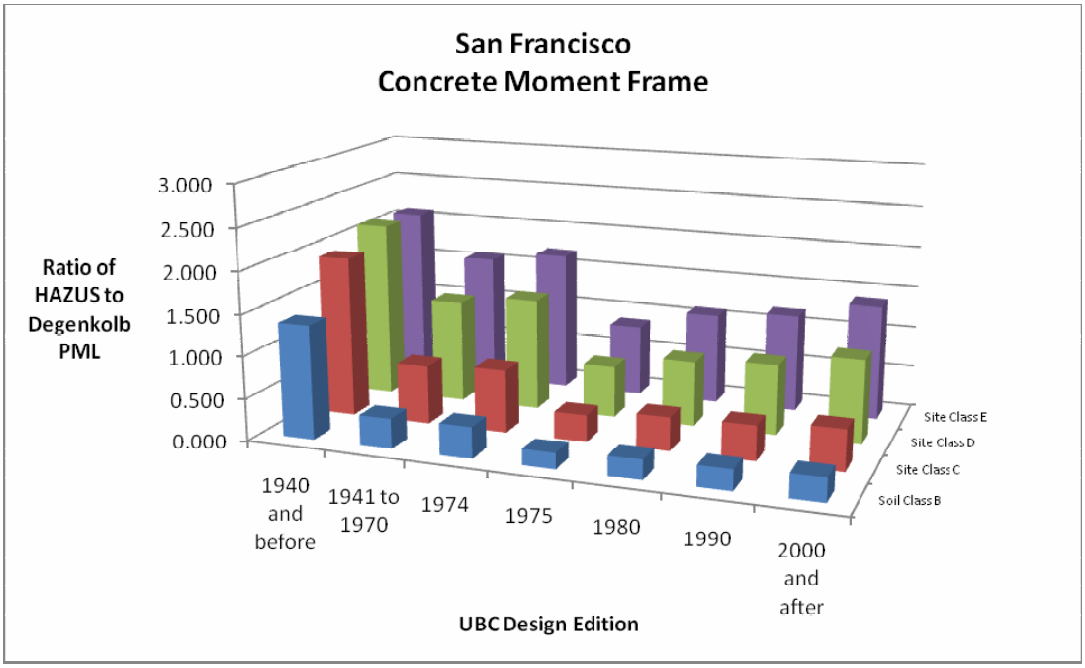

Figure 1: Seismic risk sensitivity for a site in S.F. for concrete moment frame building class.

For concrete moment frame buildings, over these test cases, the ratio of PML calculated using the HAZUS method to using the Degenkolb method varies from a low of 0.15 to a high of 2.2. HAZUS shows significantly more sensitivity to the range of ground motions associated with soft rock (Site class B) and soft soils (Site class E) than does the Degenkolb method. With HAZUS, the building quality has three discrete values depending on whether the building is older than 1941, is between 1941 and 1975, or is more recent than 1975. Within these dates, HAZUS building quality estimates are constant. With the Degenkolb method the building quality is constant prior to 1970, gradually increases between 1970 and 2000, and is constant after 2000.

For Site Class B and 1975, HAZUS predicts significantly less damage than does the Degenkolb method. HAZUS finds that the ground motion associated with Site Class B is largely non-damaging and it classifies a 1975 building as modern, high code construction. The Degenkolb method predicts that the even with Site Class B, an MMI of between VII and VIII will occur that is somewhat damaging to concrete moment frame buildings built in 1975.

For Site Class D and 1940 or older, HAZUS predicts more damage than does the Degenkolb method. HAZUS predicts that the soil amplification from Site Class D is highly damaging, and it classifies a 1940 building as lacking in all design improvements that were driven by seismic building codes. The Degenkolb method predicts that with a Site Class D, an MMI of VIII to IX occurs, but it classifies a 1940 building as having the same damageability as one built in 1965.

The following two figures show similar results for San Francisco for buildings constructed with concrete shear walls and steel moment frames:

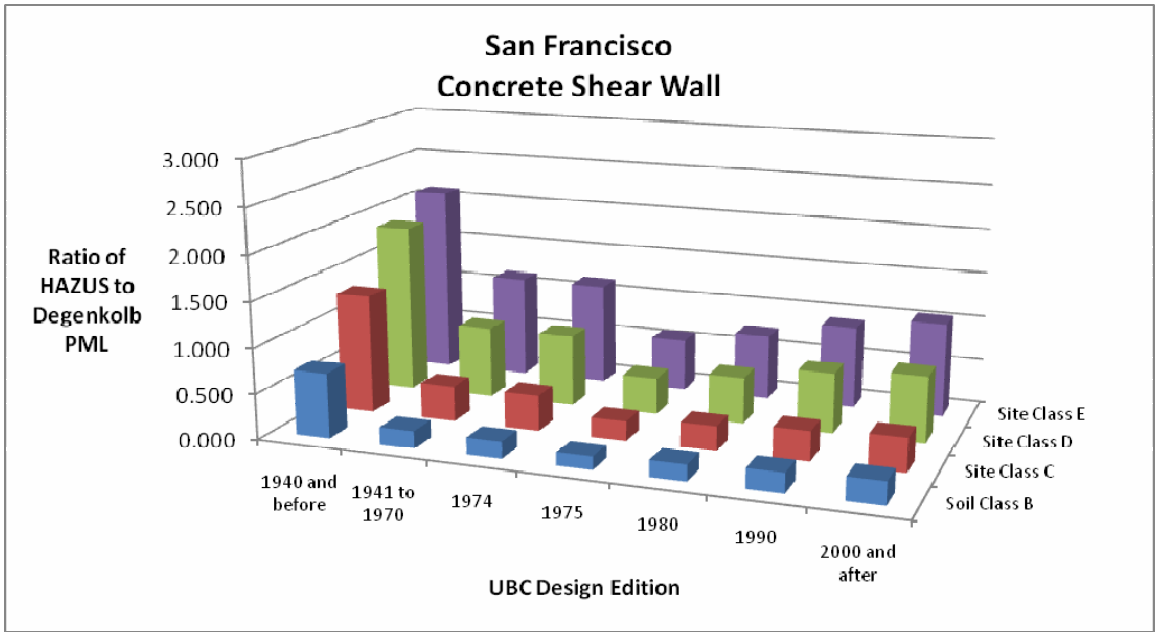

Figure 2: Seismic risk sensitivity for a site in S.F. for concrete shear wall building class.

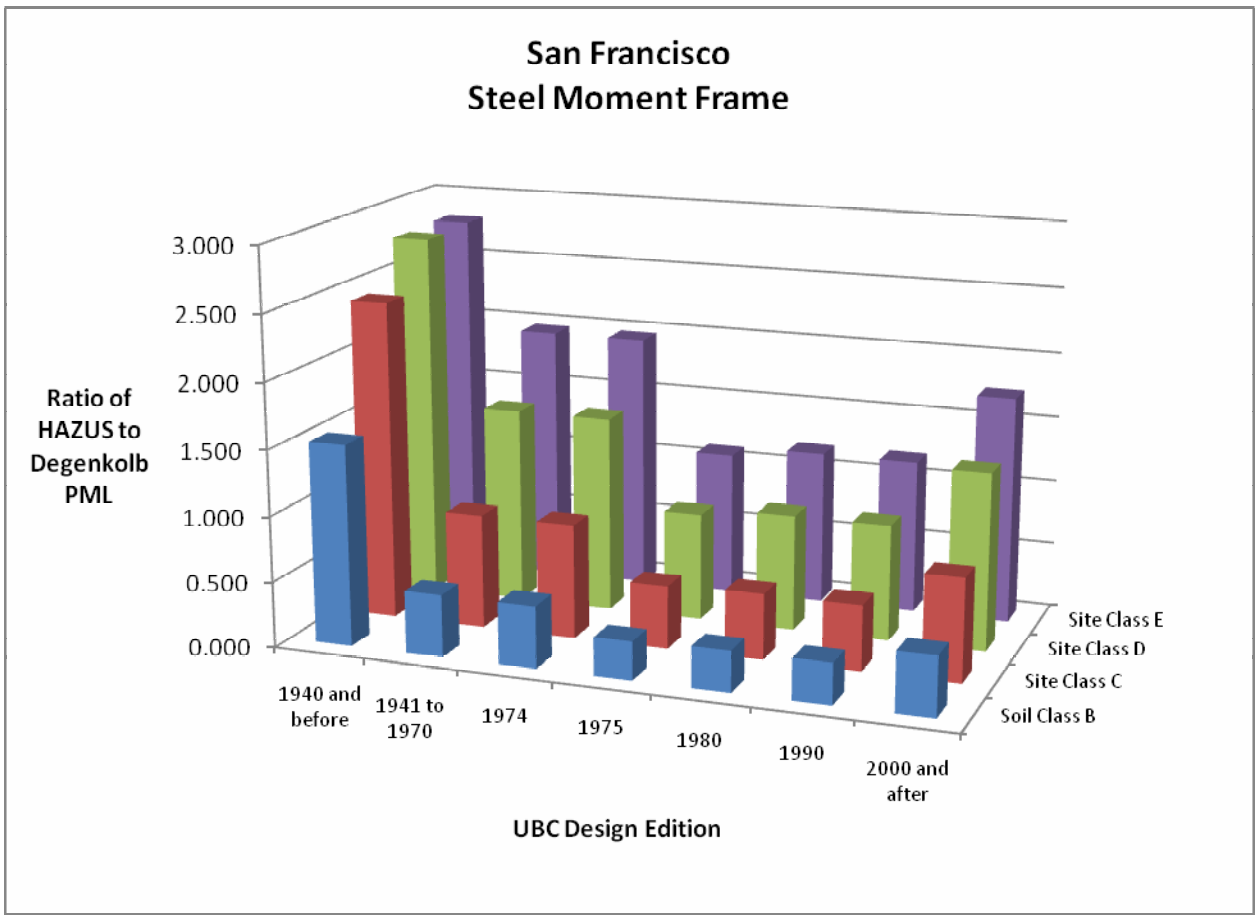

Figure 3: Seismic risk sensitivity for a site in S.F. for steel moment frame building class.

Similar patterns hold for Probable Loss values as those discussed above for PML values, indicating that the uncertainty in damage calculated from each method is reasonably consistent. The data for the test cases are included in Table 1 in the Addendum to this report.

The differences in results between these two systematic methods of damage estimation illustrates the great challenges that decision makers face in comparing seismic risk estimates from engineers using less systematic methods. Since decision makers often are not in a position to judge the absolute accuracy of risk estimates but still must make lending and insuring decisions, they should strive to standardize the risk assessment process, using either HAZUS or the Degenkolb method as standard practice.

Figures 4 through 6 contain similar comparisons for Los Angeles with similar conclusions. The data for the Los Angeles test cases is contained in Table 2 of the Addendum.

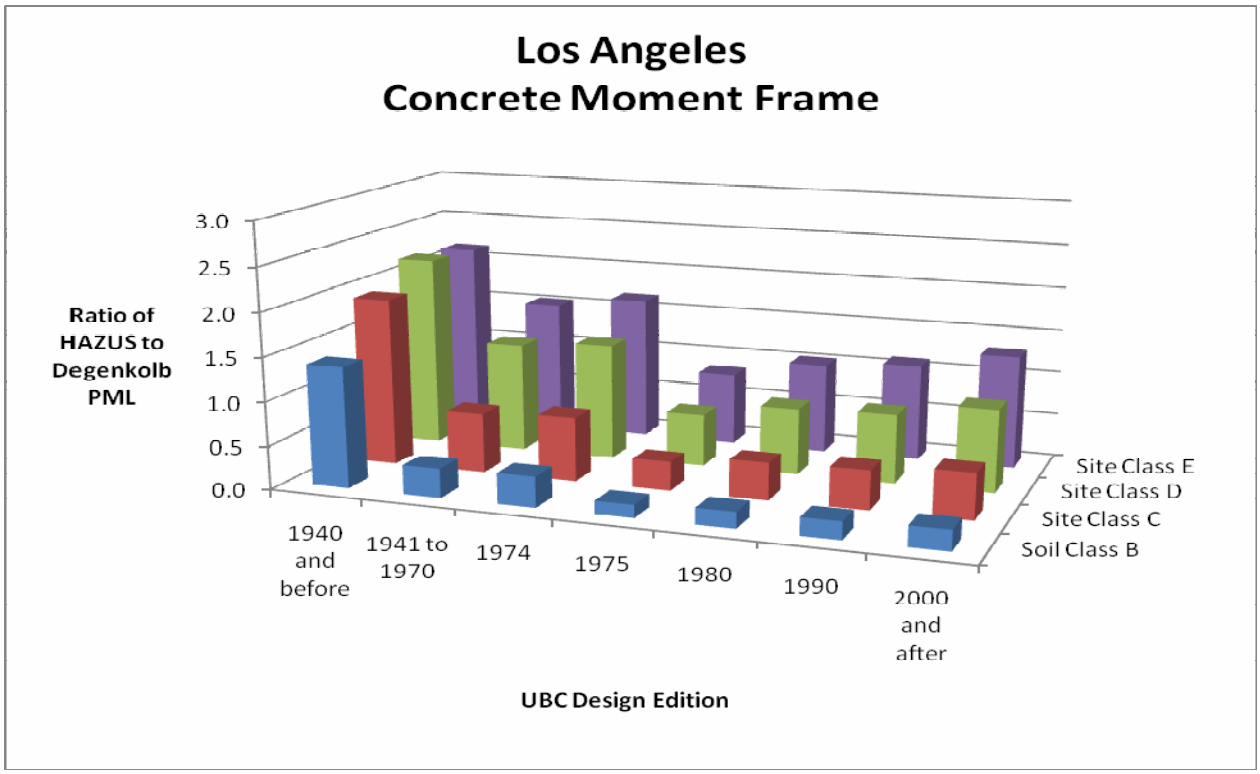

Figure 4: Seismic risk sensitivity for a site in L.A. for concrete moment frame building class.

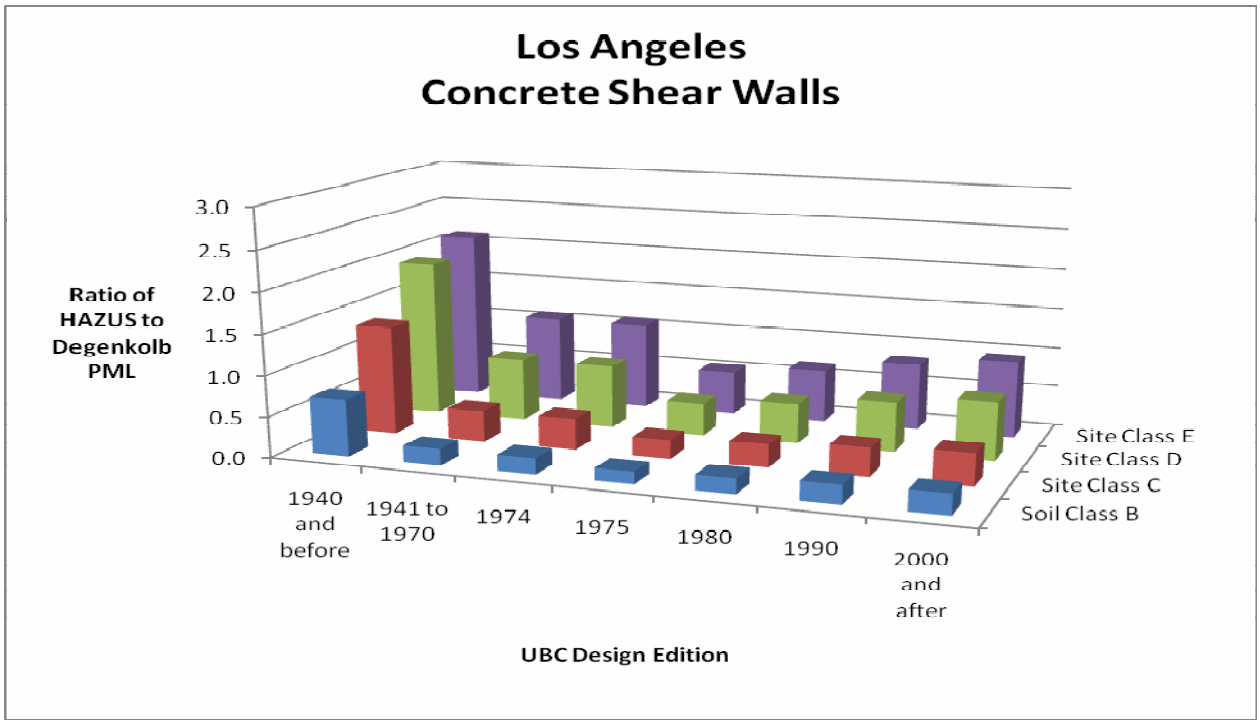

Figure 5: Seismic risk sensitivity for a site in L.A. for concrete shear walls building class.

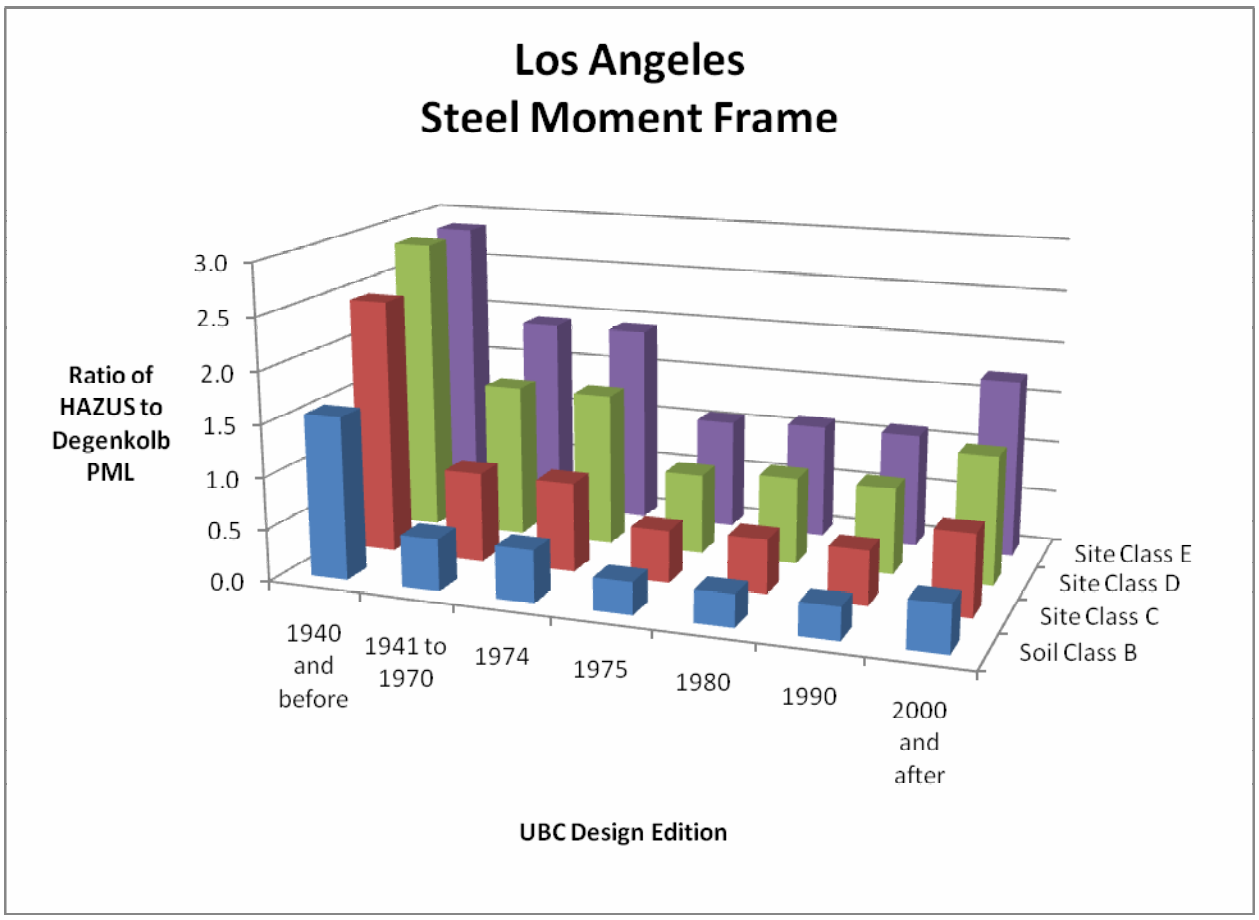

Figure 6: Seismic risk sensitivity for a site in L.A. for steel moment frame building class.

ADDENDUM

Table 1: Seismic risk sensitivity for a site in San Francisco as a function of building class, site condition, and building age.

						PML		PL	
BC Code	**Building Class Name**	**UBC Soil Class**	**UBC Design Edition**	**HAZUS Design Level**	**HAZUS**	**Degenkolb**	**PML Ratio HAZUS / Degenkolb**	**HAZUS**	**Degenkolb**	**PL Ratio HAZUS / Degenkolb**
C1	Concrete Moment Frame	B	1940 and before	Pre Code	30	22	1.364	12	11	1.091
C1	Concrete Moment Frame	B	1941 to 1970	Moderate Code	8	22	0.364	3	11	0.273
C1	Concrete Moment Frame	B	1974	Moderate Code	8	21	0.381	3	10	0.300
C1	Concrete Moment Frame	B	1975	High Code	4	21	0.190	2	10	0.200
C1	Concrete Moment Frame	B	1980	High Code	4	17	0.235	2	9	0.222
C1	Concrete Moment Frame	B	1990	High Code	4	16	0.250	2	8	0.250
C1	Concrete Moment Frame	B	2000 and after	High Code	4	14	0.286	2	7	0.286
C1	Concrete Moment Frame	C	1940 and before	Pre Code	58	30	1.933	30	17	1.765
C1	Concrete Moment Frame	C	1941 to 1970	Moderate Code	21	30	0.700	9	17	0.529
C1	Concrete Moment Frame	C	1974	Moderate Code	21	28	0.750	9	16	0.563
C1	Concrete Moment Frame	C	1975	High Code	9	28	0.321	5	16	0.313
C1	Concrete Moment Frame	C	1980	High Code	9	22	0.409	5	13	0.385
C1	Concrete Moment Frame	C	1990	High Code	9	21	0.429	5	12	0.417
C1	Concrete Moment Frame	C	2000 and after	High Code	9	18	0.500	5	10	0.500
C1	Concrete Moment Frame	D	1940 and before	Pre Code	79	37	2.135	53	23	2.304
C1	Concrete Moment Frame	D	1941 to 1970	Moderate Code	46	37	1.243	23	23	1.000
C1	Concrete Moment Frame	D	1974	Moderate Code	46	34	1.353	23	22	1.045
C1	Concrete Moment Frame	D	1975	High Code	21	34	0.618	11	22	0.500
C1	Concrete Moment Frame	D	1980	High Code	21	27	0.778	11	17	0.647
C1	Concrete Moment Frame	D	1990	High Code	21	25	0.840	11	16	0.688
C1	Concrete Moment Frame	D	2000 and after	High Code	21	21	1.000	11	14	0.786
C1	Concrete Moment Frame	E	1940 and before	Pre Code	84	40	2.100	67	28	2.393
C1	Concrete Moment Frame	E	1941 to 1970	Moderate Code	63	40	1.575	36	28	1.286
C1	Concrete Moment Frame	E	1974	Moderate Code	63	37	1.703	36	26	1.385
C1	Concrete Moment Frame	E	1975	High Code	32	37	0.865	18	26	0.692
C1	Concrete Moment Frame	E	1980	High Code	32	29	1.103	18	20	0.900
C1	Concrete Moment Frame	E	1990	High Code	32	27	1.185	18	19	0.947
C1	Concrete Moment Frame	E	2000 and after	High Code	32	23	1.391	18	16	1.125
C2	Concrete Shear Wall	B	1940 and before	Pre Code	15	21	0.714	6	12	0.500
C2	Concrete Shear Wall	B	1941 to 1970	Moderate Code	4	21	0.190	2	12	0.167
C2	Concrete Shear Wall	B	1974	Moderate Code	4	21	0.190	2	12	0.167
C2	Concrete Shear Wall	B	1975	High Code	3	21	0.143	2	12	0.167
C2	Concrete Shear Wall	B	1980	High Code	3	17	0.176	2	10	0.200
C2	Concrete Shear Wall	B	1990	High Code	3	14	0.214	2	8	0.250
C2	Concrete Shear Wall	B	2000 and after	High Code	3	12	0.250	2	7	0.286
C2	Concrete Shear Wall	C	1940 and before	Pre Code	37	28	1.321	16	17	0.941
C2	Concrete Shear Wall	C	1941 to 1970	Moderate Code	11	28	0.393	5	17	0.294
C2	Concrete Shear Wall	C	1974	Moderate Code	11	28	0.393	5	17	0.294
C2	Concrete Shear Wall	C	1975	High Code	6	28	0.214	4	17	0.235
C2	Concrete Shear Wall	C	1980	High Code	6	22	0.273	4	14	0.286
C2	Concrete Shear Wall	C	1990	High Code	6	18	0.333	4	11	0.364
C2	Concrete Shear Wall	C	2000 and after	High Code	6	16	0.375	4	10	0.400
C2	Concrete Shear Wall	D	1940 and before	Pre Code	64	34	1.882	37	22	1.682
C2	Concrete Shear Wall	D	1941 to 1970	Moderate Code	27	34	0.794	13	22	0.591
C2	Concrete Shear Wall	D	1974	Moderate Code	27	34	0.794	13	22	0.591
C2	Concrete Shear Wall	D	1975	High Code	14	34	0.412	8	22	0.364
C2	Concrete Shear Wall	D	1980	High Code	14	27	0.519	8	18	0.444
C2	Concrete Shear Wall	D	1990	High Code	14	21	0.667	8	15	0.533
C2	Concrete Shear Wall	D	2000 and after	High Code	14	19	0.737	8	13	0.615
C2	Concrete Shear Wall	E	1940 and before	Pre Code	76	36	2.111	52	25	2.080
C2	Concrete Shear Wall	E	1941 to 1970	Moderate Code	41	36	1.139	22	25	0.880
C2	Concrete Shear Wall	E	1974	Moderate Code	41	36	1.139	22	25	0.880
C2	Concrete Shear Wall	E	1975	High Code	21	36	0.583	13	25	0.520
C2	Concrete Shear Wall	E	1980	High Code	21	29	0.724	13	21	0.619
C2	Concrete Shear Wall	E	1990	High Code	21	23	0.913	13	17	0.765
C2	Concrete Shear Wall	E	2000 and after	High Code	21	20	1.050	13	15	0.867
S1	Steel Moment Frame	B	1940 and before	Pre Code	26	17	1.529	11	9	1.222
S1	Steel Moment Frame	B	1941 to 1970	Moderate Code	8	17	0.471	4	9	0.444
S1	Steel Moment Frame	B	1974	Moderate Code	8	17	0.471	4	9	0.444
S1	Steel Moment Frame	B	1975	High Code	5	17	0.294	2	9	0.222
S1	Steel Moment Frame	B	1980	High Code	5	16	0.313	2	9	0.222
S1	Steel Moment Frame	B	1990	High Code	5	16	0.313	2	9	0.222
S1	Steel Moment Frame	B	2000 and after	High Code	5	11	0.455	2	6	0.333
S1	Steel Moment Frame	C	1940 and before	Pre Code	56	23	2.435	28	13	2.154
S1	Steel Moment Frame	C	1941 to 1970	Moderate Code	20	23	0.870	9	13	0.692
S1	Steel Moment Frame	C	1974	Moderate Code	20	23	0.870	9	13	0.692
S1	Steel Moment Frame	C	1975	High Code	11	23	0.478	6	13	0.462
S1	Steel Moment Frame	C	1980	High Code	11	22	0.500	6	13	0.462
S1	Steel Moment Frame	C	1990	High Code	11	22	0.500	6	13	0.462
S1	Steel Moment Frame	C	2000 and after	High Code	11	14	0.786	6	9	0.667
S1	Steel Moment Frame	D	1940 and before	Pre Code	78	28	2.786	52	18	2.889
S1	Steel Moment Frame	D	1941 to 1970	Moderate Code	42	28	1.500	22	18	1.222
S1	Steel Moment Frame	D	1974	Moderate Code	42	28	1.500	22	18	1.222
S1	Steel Moment Frame	D	1975	High Code	23	28	0.821	13	18	0.722
S1	Steel Moment Frame	D	1980	High Code	23	26	0.885	13	17	0.765
S1	Steel Moment Frame	D	1990	High Code	23	26	0.885	13	17	0.765
S1	Steel Moment Frame	D	2000 and after	High Code	23	17	1.353	13	12	1.083
S1	Steel Moment Frame	E	1940 and before	Pre Code	84	30	2.800	66	21	3.143
S1	Steel Moment Frame	E	1941 to 1970	Moderate Code	59	30	1.967	34	21	1.619
S1	Steel Moment Frame	E	1974	Moderate Code	59	30	1.967	34	21	1.619
S1	Steel Moment Frame	E	1975	High Code	33	30	1.100	19	21	0.905
S1	Steel Moment Frame	E	1980	High Code	33	28	1.179	19	20	0.950
S1	Steel Moment Frame	E	1990	High Code	33	28	1.179	19	20	0.950
S1	Steel Moment Frame	E	2000 and after	High Code	33	19	1.737	19	13	1.462

Table 2: Seismic risk sensitivity for a site in Los Angeles as a function of building class, site condition, and building age.

					PML		PML Ratio	PL		PL Ratio
BC Code	**Building Class Name**	**UBC Soil Class**	**UBC Design Edition**	**HAZUS Design Level**	**HAZUS**	**Degenkolb**	**HAZUS / Degenkolb**	**HAZUS**	**Degenkolb**	**HAZUS / Degenkolb**
C1	Concrete Moment Frame	B	1940 and before	Pre Code	29	21	1.381	11	10	1.100
C1	Concrete Moment Frame	B	1941 to 1970	Moderate Code	7	21	0.333	3	10	0.300
C1	Concrete Moment Frame	B	1974	Moderate Code	7	20	0.350	3	10	0.300
C1	Concrete Moment Frame	B	1975	High Code	3	20	0.150	2	10	0.200
C1	Concrete Moment Frame	B	1980	High Code	3	16	0.188	2	8	0.250
C1	Concrete Moment Frame	B	1990	High Code	3	15	0.200	2	8	0.250
C1	Concrete Moment Frame	B	2000 and after	High Code	3	13	0.231	2	7	0.286
C1	Concrete Moment Frame	C	1940 and before	Pre Code	56	29	1.931	28	16	1.750
C1	Concrete Moment Frame	C	1941 to 1970	Moderate Code	20	29	0.690	9	16	0.563
C1	Concrete Moment Frame	C	1974	Moderate Code	20	27	0.741	9	15	0.600
C1	Concrete Moment Frame	C	1975	High Code	9	27	0.333	4	15	0.267
C1	Concrete Moment Frame	C	1980	High Code	9	21	0.429	4	12	0.333
C1	Concrete Moment Frame	C	1990	High Code	9	20	0.450	4	12	0.333
C1	Concrete Moment Frame	C	2000 and after	High Code	9	17	0.529	4	10	0.400
C1	Concrete Moment Frame	D	1940 and before	Pre Code	77	35	2.200	51	22	2.318
C1	Concrete Moment Frame	D	1941 to 1970	Moderate Code	44	35	1.257	21	22	0.955
C1	Concrete Moment Frame	D	1974	Moderate Code	44	33	1.333	21	21	1.000
C1	Concrete Moment Frame	D	1975	High Code	20	33	0.606	10	21	0.476
C1	Concrete Moment Frame	D	1980	High Code	20	26	0.769	10	17	0.588
C1	Concrete Moment Frame	D	1990	High Code	20	25	0.800	10	16	0.625
C1	Concrete Moment Frame	D	2000 and after	High Code	20	21	0.952	10	14	0.714
C1	Concrete Moment Frame	E	1940 and before	Pre Code	84	39	2.154	67	28	2.393
C1	Concrete Moment Frame	E	1941 to 1970	Moderate Code	60	39	1.538	34	28	1.214
C1	Concrete Moment Frame	E	1974	Moderate Code	60	36	1.667	34	26	1.308
C1	Concrete Moment Frame	E	1975	High Code	30	36	0.833	17	26	0.654
C1	Concrete Moment Frame	E	1980	High Code	30	29	1.034	17	20	0.850
C1	Concrete Moment Frame	E	1990	High Code	30	27	1.111	17	19	0.895
C1	Concrete Moment Frame	E	2000 and after	High Code	30	23	1.304	17	16	1.063
C2	Concrete Shear Wall	B	1940 and before	Pre Code	14	20	0.700	6	11	0.545
C2	Concrete Shear Wall	B	1941 to 1970	Moderate Code	4	20	0.200	2	11	0.182
C2	Concrete Shear Wall	B	1974	Moderate Code	4	20	0.200	2	11	0.182
C2	Concrete Shear Wall	B	1975	High Code	3	20	0.150	1	11	0.091
C2	Concrete Shear Wall	B	1980	High Code	3	16	0.188	1	9	0.111
C2	Concrete Shear Wall	B	1990	High Code	3	13	0.231	1	8	0.125
C2	Concrete Shear Wall	B	2000 and after	High Code	3	12	0.250	1	7	0.143
C2	Concrete Shear Wall	C	1940 and before	Pre Code	35	26	1.346	15	16	0.938
C2	Concrete Shear Wall	C	1941 to 1970	Moderate Code	10	26	0.385	5	16	0.313
C2	Concrete Shear Wall	C	1974	Moderate Code	10	26	0.385	5	16	0.313
C2	Concrete Shear Wall	C	1975	High Code	6	26	0.231	4	16	0.250
C2	Concrete Shear Wall	C	1980	High Code	6	21	0.286	4	13	0.308
C2	Concrete Shear Wall	C	1990	High Code	6	17	0.353	4	11	0.364
C2	Concrete Shear Wall	C	2000 and after	High Code	6	15	0.400	4	10	0.400
C2	Concrete Shear Wall	D	1940 and before	Pre Code	62	32	1.938	34	21	1.619
C2	Concrete Shear Wall	D	1941 to 1970	Moderate Code	25	32	0.781	12	21	0.571
C2	Concrete Shear Wall	D	1974	Moderate Code	25	32	0.781	12	21	0.571
C2	Concrete Shear Wall	D	1975	High Code	13	32	0.406	8	21	0.381
C2	Concrete Shear Wall	D	1980	High Code	13	26	0.500	8	17	0.471
C2	Concrete Shear Wall	D	1990	High Code	13	21	0.619	8	14	0.571
C2	Concrete Shear Wall	D	2000 and after	High Code	13	18	0.722	8	13	0.615
C2	Concrete Shear Wall	E	1940 and before	Pre Code	74	35	2.114	50	25	2.000
C2	Concrete Shear Wall	E	1941 to 1970	Moderate Code	38	35	1.086	21	25	0.840
C2	Concrete Shear Wall	E	1974	Moderate Code	38	35	1.086	21	25	0.840
C2	Concrete Shear Wall	E	1975	High Code	19	35	0.543	12	25	0.480
C2	Concrete Shear Wall	E	1980	High Code	19	29	0.655	12	21	0.571
C2	Concrete Shear Wall	E	1990	High Code	19	23	0.826	12	16	0.750
C2	Concrete Shear Wall	E	2000 and after	High Code	19	20	0.950	12	15	0.800
S1	Steel Moment Frame	B	1940 and before	Pre Code	25	16	1.563	10	8	1.250
S1	Steel Moment Frame	B	1941 to 1970	Moderate Code	8	16	0.500	3	8	0.375
S1	Steel Moment Frame	B	1974	Moderate Code	8	16	0.500	3	8	0.375
S1	Steel Moment Frame	B	1975	High Code	5	16	0.313	2	8	0.250
S1	Steel Moment Frame	B	1980	High Code	5	16	0.313	2	8	0.250
S1	Steel Moment Frame	B	1990	High Code	5	16	0.313	2	8	0.250
S1	Steel Moment Frame	B	2000 and after	High Code	5	11	0.455	2	6	0.333
S1	Steel Moment Frame	C	1940 and before	Pre Code	54	22	2.455	26	13	2.000
S1	Steel Moment Frame	C	1941 to 1970	Moderate Code	19	22	0.864	9	13	0.692
S1	Steel Moment Frame	C	1974	Moderate Code	19	22	0.864	9	13	0.692
S1	Steel Moment Frame	C	1975	High Code	11	22	0.500	6	13	0.462
S1	Steel Moment Frame	C	1980	High Code	11	21	0.524	6	12	0.500
S1	Steel Moment Frame	C	1990	High Code	11	21	0.524	6	12	0.500
S1	Steel Moment Frame	C	2000 and after	High Code	11	14	0.786	6	8	0.750
S1	Steel Moment Frame	D	1940 and before	Pre Code	77	27	2.852	49	17	2.882
S1	Steel Moment Frame	D	1941 to 1970	Moderate Code	40	27	1.481	20	17	1.176
S1	Steel Moment Frame	D	1974	Moderate Code	40	27	1.481	20	17	1.176
S1	Steel Moment Frame	D	1975	High Code	21	27	0.778	12	17	0.706
S1	Steel Moment Frame	D	1980	High Code	21	25	0.840	12	16	0.750
S1	Steel Moment Frame	D	1990	High Code	21	25	0.840	12	16	0.750
S1	Steel Moment Frame	D	2000 and after	High Code	21	17	1.235	12	11	1.091
S1	Steel Moment Frame	E	1940 and before	Pre Code	83	29	2.862	65	21	3.095
S1	Steel Moment Frame	E	1941 to 1970	Moderate Code	56	29	1.931	32	21	1.524
S1	Steel Moment Frame	E	1974	Moderate Code	56	29	1.931	32	21	1.524
S1	Steel Moment Frame	E	1975	High Code	31	29	1.069	18	21	0.857
S1	Steel Moment Frame	E	1980	High Code	31	28	1.107	18	20	0.900
S1	Steel Moment Frame	E	1990	High Code	31	28	1.107	18	20	0.900
S1	Steel Moment Frame	E	2000 and after	High Code	31	18	1.722	18	13	1.385