Converting HAZUS Structure Type to Structural Damage Level

Selecting model building type and code era. ShakeCast offers structural damage estimation capability adapted from the HAZUS-MH earthquake module (NIBS and FEMA 2003). For any site of interest, the user begins by selecting from the available HAZUS model building types, of which there are 36 (Table 1). "Model building type" refers to the materials of construction (wood, steel, reinforced concrete, etc.), the system used to transmit earthquake forces from the ground through the building (referred to as the lateral force-resisting system), and sometimes height category (lowrise, midrise, and highrise, which generally correspond to 1-3, 4-7, and 8+ stories, respectively).

The user must also select for each facility its building-code era, of which there are 4 (high code, moderate code, low code, and pre-code; Table 2). Code eras reflect important changes in design forces or detailing requirements that matter to the seismic performance of a building. Sixteen combinations of model building type and code era do not exist (e.g., high-code unreinforced masonry bearing wall), so in total there are 128 choices of HAZUS model building type and code era. Note that code era is largely a function of location and year built, so in principal ShakeCast2 could simplify the user's job of selecting a code era by asking for era of construction (pre-1941, 1941-1975, or post-1975) instead, and looking up the code era via internal GIS database.

Describing damage. The user selects between 3 and 4 alert levels, meaning that any facility affected by an earthquake is noted green, yellow, or red (3 levels), or alternatively green, yellow, orange, or red (4 levels). These colors index the likely structural damage state of the facility, in HAZUS terms: green corresponds to HAZUS' undamaged or slight structural damage states, yellow corresponds to moderate structural damage, orange to extensive structural damage, and red to complete structural damage. These terms (slight, moderate, etc.) are described via likely effects of the earthquake on the structural system. For example, for a small woodframe building (W1, regardless of code era), "green" corresponds to "Undamaged or small plaster or gypsum-board cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneer." These descriptions can be found in the HAZUS-MH Technical Manual (NIBS and FEMA 2003) Section 5.3.1.

Relating seismic excitation to structural damage. When an earthquake occurs, its shaking intensity at each facility location is estimated in terms of peak horizontal ground acceleration (PGA). Buildings and ground motions are highly variable, even given a model building type and PGA level, so it is uncertain the exact level of PGA that will cause a given facility to experience structural damage of any particular level. The relationship between PGA and damage state is therefore probabilistic, meaning for example that one can estimate the *probability* of a given building experiencing a given structural damage state when the building experiences a certain level of PGA. It is more convenient here to estimate the PGA at which there is a given probability of damage exceeding a given structural damage state. In ShakeCast, a facility is indicated as damage level *x* (i.e., green, yellow, orange, or red) when the PGA is such that there is at least a 50% probability of the corresponding HAZUS structural damage state and less than a 50% probability of the next-higher HAZUS structural damage state. These PGA values are taken from the HAZUS-MH Technical Manual Table 5.14a-d.

Tabular lookup data. Two lookup files in CSV format are provided with this memo, one for a 3-level damage scheme, the other for a 4-level damage scheme. Each has 7 columns or fields, listed in Table 3. The fields correspond to data appearing in the ShakeCast2 Facility Administration screen.

Table 1. HAZUS-MH earthquake model building types (NIBS and FEMA 2003 Table 3.1)

No.	Label	Description	Height			
			Range		Typical	
			Name	Stories	Stories	Feet
1	W1	**Wood, Light Frame (≤ 5,000 sq. ft.)**		1 - 2	1	14
2	W2	**Wood, Commercial and Industrial (>5,000 sq. ft.)**		All	2	24
3	S1L	**Steel Moment Frame**	Low-Rise	1 - 3	2	24
4	S1M		Mid-Rise	4 - 7	5	60
5	S1H		High-Rise	8+	13	156
6	S2L	**Steel Braced Frame**	Low-Rise	1 - 3	2	24
7	S2M		Mid-Rise	4 - 7	5	60
8	S2H		High-Rise	8+	13	156
9	S3	**Steel Light Frame**		All	1	15
10	S4L	**Steel Frame with Cast-in-Place Concrete Shear Walls**	Low-Rise	1 - 3	2	24
11	S4M		Mid-Rise	4 - 7	5	60
12	S4H		High-Rise	8+	13	156
13	S5L	**Steel Frame with Unreinforced Masonry Infill Walls**	Low-Rise	1 - 3	2	24
14	S5M		Mid-Rise	4 - 7	5	60 156
15	S5H		High-Rise	8+	13	
16	C1L	**Concrete Moment Frame**	Low-Rise	1 - 3	2	20
17	C1M		Mid-Rise	4 - 7	5	50
18	C1H		High-Rise	8+	12	120
19	C2L	**Concrete Shear Walls**	Low-Rise	1 - 3	2	20
20	C2M		Mid-Rise	4 - 7	5	50
21	C2H		High-Rise	8+	12	120
22	C3L	**Concrete Frame with Unreinforced Masonry Infill Walls**	Low-Rise	1 - 3	2	20
23	C3M		Mid-Rise	4 - 7	5	50
24	C3H		High-Rise	8+	12	120
25	PC1	**Precast Concrete Tilt-Up Walls**		All	1	15
26	PC2L	**Precast Concrete Frames with Concrete Shear Walls**	Low-Rise	1 - 3	2	20
27	PC2M		Mid-Rise	4 - 7	5	50
28	PC2H		High-Rise	8+	12	120
29	RM1L	**Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms**	Low-Rise	1-3	2	20
30	RM2M		Mid-Rise	4+	5	50
31	RM2L	**Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms**	Low-Rise	1 - 3	2	20
32	RM2M RM2H		Mid-Rise	4 - 7	5	50
33			High-Rise	8+	12	120
34	URML	**Unreinforced Masonry Bearing Walls**	Low-Rise	1 – 2	1	15
35	URMM		Mid-Rise	3+	3	35
36	MH	**Mobile Homes**		All	1	10

Table 2. HAZUS-MH Guidelines for Selection of Damage Functions for Typical Buildings Based on UBC Seismic Zone and Building Age (NIBS and FEMA 2003 Table 5.20)

UBC Seismic Zone (NEHRP Map Area)	**Post-1975**	**1941 - 1975**	**Pre-1941**
Zone 4 (Map Area 7)	High-Code	Moderate-Code	Pre-Code (W1 = Moderate-Code)
Zone 3 (Map Area 6)	Moderate-Code	Moderate-Code	Pre-Code (W1 = Moderate-Code)
Zone 2B (Map Area 5)	Moderate-Code	Low-Code	Pre-Code (W1 = Low-Code)
Zone 2A (Map Area 4)	Low-Code	Low-Code	Pre-Code (W1 = Low-Code)
Zone 1 (Map Area 2/3)	Low-Code	Pre-Code (W1 = Low-Code)	Pre-Code (W1 = Low-Code)
Zone 0 (Map Area 1)	Pre-Code (W1 = Low-Code)	Pre-Code (W1 = Low-Code)	Pre-Code (W1 = Low-Code)

Table 3. Layout of damage lookup tables

Field name	**Type**	**Description**
ID	Integer	A unique index
Facility Type	String	HAZUS model building type and seismic design level
Color	String	Green, Yellow, Orange, or Red
Damage Level	String	Equivalent HAZUS structural damage level(s)
Low Limit	Integer	Intensity with 50% probability of this damage level occurring
High Limit	Integer	Intensity with 50% probability of next damage level occurring
Metric	String	Intensity metric

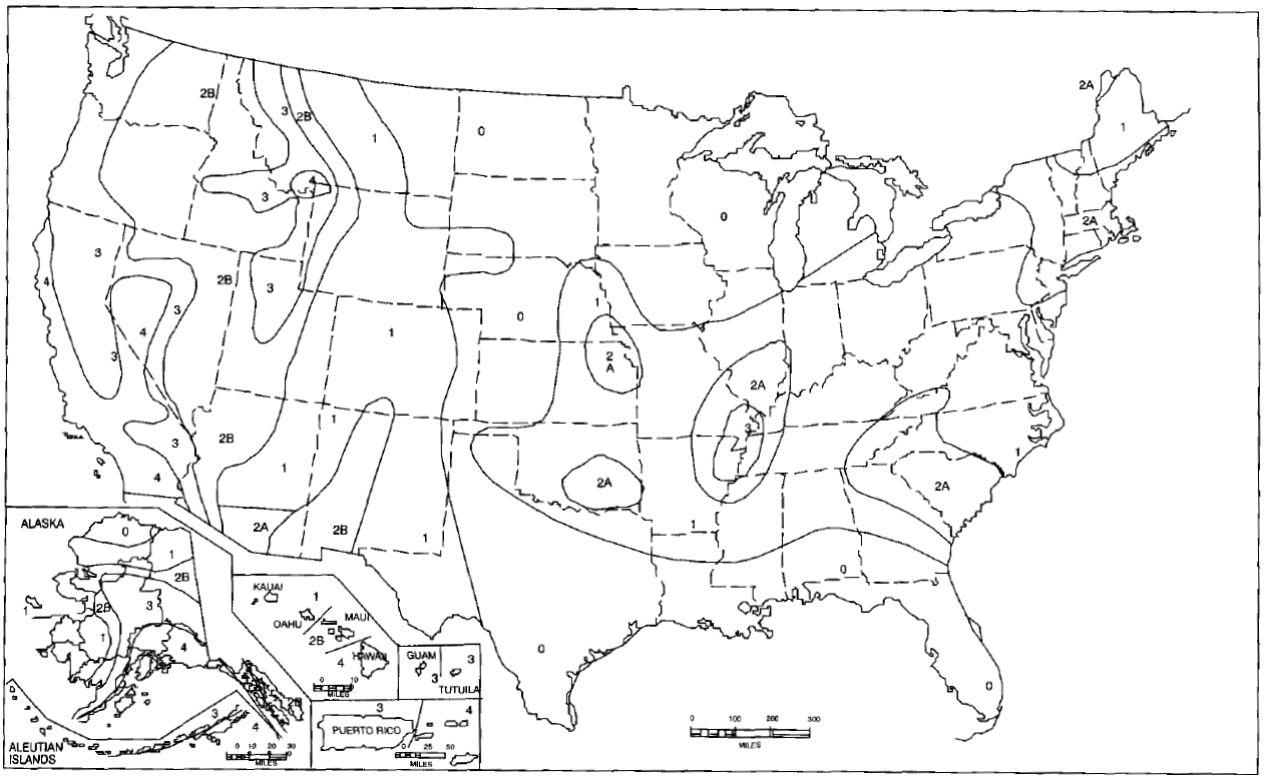

Figure 1. Seismic zone map of the United States (ICBO 1997 Fig. 16-2)

REFERENCES CITED

(ICBO) International Conference of Building Officials, 1997. *Uniform Building Code*, Whittier, CA.

(NIBS and FEMA) National Institute of Building Sciences and Federal Emergency Management Agency, 2003. *Multi-hazard Loss Estimation Methodology, Earthquake Model, HAZUS®MH Technical Manual,* Federal Emergency Management Agency, Washington, DC, 690 pp.