Analysis of Collapse Fragilities of Global Construction Types Obtained During WHE-PAGER Phase I Survey

Kishor Jaiswal and David Wald U.S. Geological Survey, Golden, CO 80401.
(Email: kjaiswal@usgs.gov)

Overview:

The WHE-PAGER project is an ongoing collaborative effort, initiated by a group of experts from World Housing Encyclopedia (WHE) and U.S. Geological Survey's PAGER project, for an initial estimate of building inventory and vulnerability worldwide. The World Housing Encyclopedia's housing prototype database (which is available online at http://www.world-housing.net), covers only residential building types and lacks information pertaining to (1) nonresidential building types, (2) the fraction of building types in rural or urban areas, (3) vulnerability characteristics (through both empirical and analytical approaches), and (4) occupancy characteristics (day and night occupancy patterns). The WHE-PAGER project provides a framework for compilation of this information in a simple and consistent format solicited mainly from earthquake engineering professionals from different countries. The data compiled in this exercise will also help in enhancing the housing stock distribution and vulnerability data for the existing WHE housing reports for different countries. Country-specific experts have been requested to provide their best estimate of the relative abundance of predominant building types in their country, the probability of collapse as a function of intensity for these building types, and the fraction of the urban and rural population who live and work in each building type. These estimates are only first-order approximations, and they are not meant to substitute for the more sophisticated modeling and analysis work that is taking place in some countries. Rather, the estimates provided here are meant to complement such efforts, and to be a first step in promoting the need for development of a rigorous database throughout the world. Similarly, the inventory-specific information compiled in the WHE-PAGER project provides a broad occupancy pattern of human exposure in urban, rural, residential or nonresidential dwellings by its construction types.

Within a year's time span, the WHE-PAGER survey resulted in a development of comprehensive inventory-specific information for 25+ countries (Table 1 & Appendix 1) in a standardized format covering specified aspects of human occupancy pattern, construction types and vulnerability for individual countries (http://www.world-housing.net/psearch1.php?pr=Array). These estimates are based on expert judgment to provide an order-of-magnitude, broad overview of vulnerability in a particular country.

Analysis:

Comparative analysis of the Phase I data specific to vulnerability of building types is also illustrated in the subsequent section of the report. It is evident that experts have taken considerable efforts to evaluate the existing data in their country (both inventory and vulnerability). We recognize that some of the data provided in the forms are based upon the subjective judgment of individuals who have drawn on their experience and expertise but, potentially, very limited data available in their country. The expert-opinion vulnerability information defined in terms of the collapse probability of a given structure type to shaking intensity was meant to represent average conditions, and is not intended to reflect extreme or specific occurrences. Analysis of the Phase I data, clearly indicates that there are large variations (from country to country) in terms of expert's judgment on the estimate of the collapse probability for the same class of structures. The variation of collapse probability estimates is obvious and may be, in part, expected even for same class of structure due to potentially large variations in building design and construction practices from country to country and even within a country (rural vs. urban; pre or post code or level of building code enforcement). However, several of the estimates appear to be biased towards one side (in this case, a consistent overestimation in terms of structure's vulnerability; see values associated with asterisk in Appendix 1) and we hope that this report will help the experts to compare the structure-specific vulnerability estimates from different countries.

We suggest three potential contributions to the general trend of the bias toward higher vulnerability estimates:

1) Availability (sampling) bias. There may be a tendency to relate intensities to occurrences of building collapse, without sufficient consideration (or awareness) of lower collapse rates in adjacent areas which may have experience comparable ground motions [resulting in higher bias].
2) Tabulated accelerations associated with intensities on the questionnaire may be more representative of California relations (where they were derived) than average values determined in other, more vulnerable regions) [resulting in high bias].
3) Definitions for collapse were vague; it was not clearly stated that the intent was to determine collapse levels consistent with EMS and those associated with casualties [resulting in high bias].

In addition to those above, another source of bias might be due to lack of evidence of performance of a country-wide building stock at the higher intensity range, leading to overestimates of vulnerability from extrapolation.

It should also be noted that vulnerabilities for engineered structures are usually sufficiently consistent across countries, while values of vulnerability related to non–engineered, non-codified, and vernacular building types differ greatly and usually estimates are higher than the equivalent class of vulnerability defined by the EMS-98. This might be due to a cultural bias or lack of confidence for assigning the performance of non-seismically designed buildings, again leading to a conservative judgment.

Recommendations:

The review of the data collected so far and the feedback received from the experts have helped in the development of a modified questionnaire form and improved data collection guidelines. Based on analysis of the initial Phase I survey data, we suggest the following improvements:

a. Provide a range of collapse probability estimates based on the EMS to give baseline guidance to the experts.
b. Improve the guideline document to provide a clearer definition of collapse with respect to shaking intensity. Guideline document should also include illustrative photographs of collapse definitions for masonry and framed constructions.
c. Provide and use the PAGER structure type list.
d. Avoid PGA-MMI mapping as it may vary depending upon tectonic environment.

We gratefully acknowledge the contributions made by WHE experts during the WHE-PAGER Phase I survey.

Table 1. List of countries that provide inventory data obtained during WHE-PAGER survey and the name of the experts

Sr. No.	Country	Name of Expert
1.	Algeria	Mohammed N. Farsi, Farah Lazzali
2.	Chile	María Ofelia Moroni
3.	China	Sun Baitao/Zhang Guixin/Chen Honfu
4.	Colombia	Luis G. Mejia
5.	Cyprus	Vsevolod Levtchitch
6.	France	Thibault Christian
7.	Germany	Sergey Tyagunov, Lothar Stempniewski, Christian Münich
8.	India	Form 1. C.V.R. Murty; Form 2. Kishor Jaiswal
9.	Indonesia	Sugeng Wijanto
10.	Ireland	Robin Spence
11.	Italy	Agostino Goretti
12.	Japan	Charles Scawthorn
13.	Mexico	Sergio M. Alcocer
14.	Nepal	Jitendra K Bothara
15.	Pakistan	Qaisar Ali
16.	Peru	Alejandro Muñoz
17.	Spain	Alex H. Barbat
18.	Switzerland	Kerstin Pfyl-Lang
19.	Thailand	Chitr Lilavivat
20.	Turkey	Form 1. Polat Gülkan/Ahmet Yakut; Form 2. Mustafa Erdik
21.	United Kingdom	Robin Spence
22.	Slovenia	Mariana Lutman
23.	New Zealand	Jim Cousins
24.	Macedonia	Mihail Garevski
25.	Russia	Jacob Eisenberg
26.	Greece	Form 1. Antonius Pomonis; Form 2 Andreas Kappos.

Analysis of Phase I data :

(a) Stone masonry structures:

Structure Type	*Statistics*	*Collapse Probability (%)*			
		VI	VII	VIII	IX
Rubble stone masonry structure	**Median**	2.5	10.0	37.4	75.0
	Mean	8.5	21.1	39.0	70.0
	Sample Std Dev.	18.5	27.8	30.1	24.0

(b) Adobe/mud structures:

Structure Type	*Statistics*	*Collapse Probability (%)*			
		VI	VII	VIII	IX
Adobe/mud structure	**Median**	10.0	40.0	70.0	90.0
	Mean	18.5	46.4	73.0	90.7
	Sample Std Dev.	23.1	28.6	20.1	10.5

(c) Clay brick masonry structures:

Structure Type	*Statistics*	*Collapse Probability (%)*			
		VI	VII	VIII	IX
Clay brick / block Masonry	**Median**	2.0	9.4	22.5	62.0
	Mean	6.1	18.6	34.4	58.4
	Sample Std Dev.	12.2	21.6	30.9	34.9

(d) Concrete moment frame designed for gravity loads:

Structure Type	*Statistics*	*Collapse Probability (%)*			
		VI	VII	VIII	IX
Concrete MRF (Class 14)	**Median**	0.0	2.0	10.0	35.0
	Mean	1.7	9.5	23.7	41.5
	Sample Std Dev.	3.5	15.5	29.8	33.5

(e) Concrete MRF designed for earthquake loads:

Structure Type	*Statistics*	*Collapse Probability (%)*			
		VI	**VII**	**VIII**	**IX**
Concrete MRF (Class 15/16)	**Median**	0.0	1.0	4.0	15.0
	Mean	0.7	2.4	6.9	18.4
	Sample Std Dev.	1.6	5.1	10.1	15.3

(f) Wooden structures of different types:

Structure Type	*Statistics*	*Collapse Probability (%)*			
		VI	**VII**	**VIII**	**IX**
Wooden constructions	**Median**	0.0	2.5	10.0	30.0
	Mean	3.9	11.7	22.6	37.1
	Sample Std Dev.	7.3	20.7	30.2	33.3

Appendix-1.

WHE-PAGER Survey data (Phase I)

Country Name	WHE Structure type	MMI/EMS/MSK				RES		NON-RES		PAGER-STR
		VI	VII	VIII	IX	Urban	Rural	Urban	Rural	
Algeria	Masonry- Adobe block walls	7	22	50	75	2	15	0	0	A
	Masonry- Field Stone Masonry	3	14	40	65	20	15	2	15	RS
	Structural Concrete-Moment resisting frame designed for gravity load	3	11	33*	50*	55	40	40	40	C3
	Structural Concrete-Moment resisting frame designed with seismic features	1	4	13	37	15	25	35	40	C1
	Structural Concrete-Moment resisting frame/frame with shear walls-Dual system	0	1.5	5	24	5	5	20	5	C6
	Structural Concrete-Shear wall structure	0	0.1	1	5	3	0	2	0	C2
	Steel-Moment resisting frame with brick masonry partitions	0	0.4	6	23	0	0	1	0	S5
						100	100	100	100	
Chile	Braced Steel Frame (mostly industrial use)	0	0	0	2	1	0	27	20	S2
	Reinforced concrete shear walls	0	0	0	1	25	1	46	20	C2
	Reinforced masonry	0	0	5	10	15	16	7	12	RM
	Confined masonry	0	0	2	5	13	14	8	11	RM3
	Partially reinforced or confined masonry (Hybrid masonry)	0	5	20	30	32	34	0	0	RM
	Unreinforced stone masonry	0	20	60*	90*	0	1	0	0	RS
	Adobe	0	10	55*	85*	1	2	0	1	A
	Wood	0	0	5	10	11	18	5	13	W
	Others					2	14	7	23	INF

						100	100	100	100	
China	Stone Masonry Walls (2)	8	35*	57*	80*	1.5	2.5	1	2.5	RS
	Earthen/Mud/Adobe/Rammed Earthern Walls, (4)(5)(6)(7)	15*	42*	75*	90*	4	40	0	4	RE
	Clay Brick/ block masonry walls (7)(8) (South Part)*	5	12	30	62	5	35	5	8.5	UFB1
	Clay Brick/ block masonry walls (7)(8) (North Part)*	3	8	25	51	5	35	5	8.8	UFB2
	Clay Brick/ block masonry walls (9) (South Part)*	2	5	20	42	64.5	10	55	75	UFB4
	Clay Brick/ block masonry walls (9) (North Part)*	1	4	14	35	64.5	10	55	75	UFB5
	Concrete Block Masonry	3	5	15	38	2	0	2	0	UCB
	Moment Resisting Frame (14)	0	0	8	20	5	3	0	5	C3
	Moment Resisting Frame (15)(16)(17)	0	0	1	5	12	0	20	0	C1
	Shear Wall Structure (19)(20)(21)(22)	0	0	1	3	5	0	12	0	C2
	Moment Resisting Frame (23)(24)(25)	0	0	2	5	0	0	3	0	S4
	Wooden Structures	3	9	15	45	5	9.5	2	5	W
						104	100	100	100.3	
Colombia	Mud walls with horizontal wood elements	20*	50*	80*	100*	2	35	5	40	M2
	Unreinforced brick masonry in cement mortar	10*	50*	80*	100*	30	30	30	15	UFB4
	Confined brick/block masonry with concrete posts/tie columns beams	5	15	40	60	10	2	5	5	RM3
	Concrete block masonry designed for gravity loads only	10*	40*	80*	100*	15	3	30	5	C3
	Concrete block masonry designed with seismic features (diff. ages)	0	20	40*	80*	15	1	10	5	C1
	Moment resisting concrete frame with unreinfoced masonry infill	5	10	20	40	15	0	10	5	C1
	Moment resisting frame with concrete shear walls-dual system	0	5	10	20	5	0	0	0	C6
	Shear walls cast in-situ	0	0	10	15	1	0	0	0	C2

	Moment resisting steel frame with brick masonry partitions	0	5	10	25	1	0	0	0	S5
						94	71	90	75	
Cyprus	Massive stone masonry in lime mortar	15*	45*	98*	100*	2	5	4	5	MS
	Adobe block walls	25*	85*	100*	100*	7	10	7	11	A
	Unreinforced clay brick masonry in cement mortar with reinforced concrete slab	5	30*	65*	100*	3	5	3	5	UFB5
	R.C. moment resisting frames with unreinforced masonry infill	0	15	40*	90*	48	43	42	34	C3
	R.C. moment resisting frames with unreinforced masonry infill	0	1	10	35*	30	35	28	39	C1
	Moment resisting frame with concrete shear walls	0	0	5	15	10	1	14	5	C2
	Steel moment resisting frames	0	0	2	10	0	0	2	0	S1
	Stud wall frame with plywood sheathing	0	0	1	15	0	1	0	1	W1
						100	100	100	100	
France	Rubble Stone (1)	0-5	3-8	5-24	18-70*	?	?	?	?	RS
	Massives Stone +(Lime or Cement) without ties + Wood Slabs (2)	0-3	2-5	4-19	16-54*	?	?	?	?	MS
	Clay Bricks +(Lime or Cement) +(RC Floor/Roof Slabs) (9)	0-2	0-4	3-17	14-47	?	?	?	?	UFB5
	Confined Bricks + Concrete Posts/Ties and Beams (10)	0	0-2	0-12	10-38	?	?	?	?	RM3
	Concrete Blocks +(Lime or Cement) +without ties (11)	0-3	2-5	4-18	15-50	?	?	?	?	UCB
	Concrete Blocks +(Lime or Cement) +with ties (12)	0-2	0-4	3-16	13-45	?	?	?	?	RM2
	Only Gravity Loads (14)	0-3	0-5	4-20	10-55*	60-100	60-100	?	?	C3
	Seismic Features (15)	0	0-2	0-12	6-40*	1-10	<1	?	?	C1
	Moment Resisting Frame + Unreinforced Masonry Walls (16)	0-2	0-3	3-14	12-45	?	?	?	?	C1

	Shear Walls Cast In Situ (21)	0	0-2	0-10	8-36	?	?	?	?	C2
Germany	Stone masonry walls (2)	0	0-2	5-20	30-60	very low	low	very low	very low	DS
	Unreinforced brick masonry in cement mortar (various floor/roof systems) (9)	0	0-1	2-10	10-30	moderate	moderate	moderate	moderate	UFB5
	Unreinforced concrete block masonry in cement mortar (various floor/roof systems) (11)	0	0-1	2-10	10-30	low	low	low	low	UCB
	Reinforced masonry in cement mortar (various floor/roof systems) (12)	0	0	1-5	5-20	low	low	low	low	RM2
	RC frame with unreinforced masonry infill walls (16)	0	0	1-5	5-20	moderate	low	moderate	moderate	C3
Greece1 (A. Pomonis)	Rubble (field) stone masonry usually on lime mortar with wooden floors (it also contains cut-stone masonry and some buildings of class 2 in urban areas). 86% built pre-1960. Usually 1 or 2 storeys. Also contains some adobe (4) buildings (all pre-1960) (1)	0	7	21	40	1.1	20.6	5.1	23.8	RS3 or DS2
	Unreinforced brick masonry usually with cement mortar and RC floors (it also contains in smaller fractions some class 7, 8 buildings). Mostly pre-1960. Usually 1-2 storeys. Also contains Concrete block (13) masonry (usually unreinforced) with RC floors (it also contains in smaller fractions some class 11, 13 buildings). Usually post-1960. Usually 1-2 storeys..(9)	0	2.5	7.5	16	2.3	20.6	9.7	28.6	UFB5
	Wooden (post and beam frame); it also contains some class 31 buildings). Usually 1-2 storeys. (29)	0	0	0.2	0.35	0.1	0.3	0.3	0.5	W6 & W7
	Steel MRF with unreinforced clay brick masonry infill-partition walls (usually up to 3 floors). 96% after 1960 (30% after 1995). (23)	0	0.03	0.25	0.5	0	0	0.4	0.4	S5
	RC MRF with unreinforced clay brick masonry infill-partition walls. Built prior to 1961 (no code). Low-rise (1-2 floors). (14)	0	0.25	0.75	1.15	0	0	0.4	0.4	C3L
	RC MRF with unreinforced clay brick masonry infill-partition walls. Built in 1961-1995 (low code). Low-rise (1-2 floors). (16)	0	0	0.25	0.4	12	22.1	12.2	19.5	C1L

	RC MRF with unreinforced clay brick masonry infill-partition walls. Built after 1995 (high code). Low-rise (1-2 floors). (16)	0	0	0	0.2	2.1	7.1	2.9	6.8	C1L
	RC MRF with unreinforced clay brick masonry infill partition built prior 1961 (no code), mid rise(3-8 floors) (14)	0	0.17	0.45	0.7	7.9	2	6.5	1	C3M
	RC MRF with unreinforced clay brick masonry infill partition (between 1961-1995)low code, mid rise (3-8 floors) Very few 9-11 storey also contained. (Greece has only 51 buildings that exceed 11 storeys). (16)	0	0	0.2	0.35	62.2	18.9	49.5	13.2	C1M
	RC MRF with unreinforced clay brick masonry infill partition post 1995, high code, mid rise (3-8 floors). Very few 9-11 storey buildings also contained (16)	0	0	0	0.18	10.9	6.1	11.8	4.6	C1M
						98.6	97.7	98.8	98.8	
Greece2 (A. Kappos)	R/C Moment Resisting Frames Old Codes - Pre 1985	0.05	0.1	0.35	1	50	25			C3
	R/C Moment Resisting Frames Old Codes - Post 1985	0	0.05	0.1	0.4	7.5	9			C1
	R/C Dual Structures (Frames & Shear Walls) Old Codes - Pre 1985	0.01	0.1	0.25	0.75	12.5	3			C6
	R/C Dual Structures (Frames & Shear Walls) Old Codes - Post 1985	0	0.01	0.05	0.35	22	9			C6
	Stone masonry	3	5	10	55	1.5	23			RS
	Unreinforced brick masonry	0	0.1	1	7.5	5.5	30			UFB
						99	99			
India1 (C. Murty)	Mud and Unburnt Brick Houses	60*	90*	100*	100*	11.2	37.1	3	20	A1
	Stone Masonry Houses	45*	60*	95*	100*	7.2	11.5	20	4	RS
	Grass, Thatch, Bamboo, etc., Houses	20	50	80*	95*	3.6	12.5	1	4	W5
	Unreinforced Clay Brick Masonry Wall Houses	10	40	65*	85*	68.7	35.3	35	25	UFB
	RC Moment Resisting Frame Buildings (Gravity Designed Frame)	0	15	30	65*	6	1.3	40	0	C3
						96.7	97.7	99	53	
India2	Rubble stone in mud mortar	0-5	6-10	11-24	25-80	5	11	2	2	RS2

(K. Jaiswal)	Unreinforced brick masonry in mud mortar with timber	0-1	2-5	6-24	25-60	4.5	15	2	4	UFB2
	Unreinforced brick masonry in cement mortar with reinforced concrete floor/roof slabs	0-1	2-5	6-24	25-40	42	27	30	45	UFB5
	Unreinforced concrete block masonry in lime/cement mortar	0-1	0-5	6-24	25-52	1	0	1	0	UCB
	Adobe block walls	0-10	11-20	21-40	41-90	4	28	0	1	A
	Concrete moment resisting frames designed for gravity loads only	0-1	0-5	6-10	11-40	22	6	32	20	C3
	Concrete moment resisting frames designed with seismic features	0	0-1	0-5	6-24	2	0	10	1	C1
	Concrete moment resisting frames with unreinforced masonry infill walls	0	0-1	2-10	11-30	17	0	20	25	C1
	Load-bearing timber frame thatch	0-1	0-5	6-10	11-50	0.5	2	0	0	W
	Load-bearing timber frame walls with bamboo/reed (wattle & daub)	0-5	6-10	11-24	25-80	0.5	5	0	0	W5
	Load-bearing timber frame with stone/brick masonry infill	0-5	6-10	11-24	25-40	1	1	0	0	W6
	Light Steel Frame (Usually for work/warehouse facilities)	0	0-1	0-5	6-10	0	0	2	0.5	S3
	Rubble stone in lime mortar with timber (Gable) roofing	0-5	6-10	11-24	25-60	0.5	5	1	1.5	RS3
						100	100	100	100	
Indonesia	Unreinforced brick masonry in cement mortar with reinforced concrete slab (9)	50*	70*	80*	90*	12	40	5	15	UFB5
	Confined brick/block masonry with concrete posts/tie columns (10)	40*	60*	70*	80*	40	15	10	25	RM3
	Structural concrete frame with unreinforced masonry infill walls (16)	10*	30*	40*	60*	15	5	35	30	C3
	Precast frame structure (18)	0	0	0	0	3	0	4	0	PC3
	Frame with concrete shear walls-dual system (19)	0	5	10	20	10	0	15	0	C6
	Steel moment-resisting frame with brick masonry partitions (23)	5	20	40*	50*	5	0	14	5	S5
	Steel braced frame concentric (26)	0	5	15	30	0	0	17	0	S2
	Wooden structures with post and beam frame (29)	5	20	30	40	10	30	0	15	W6
	Wooden structures frame with brick masonry infill (31)	10*	30*	40*	50*	5	10	0	10	W7
						100	100	100	100	

Ireland	Brick masonry, weak (lime) mortar	0	0.6	4	15*	25	30	50	50	UFB3
	Brick masonry, cement mortar, timber floors	0	0.1	1	6*	74	70	20	30	UFB4
	RC frame, non-seismic but designed for gravity loads	0	0.2	2	11	1	0	20	15	C3
	Steel frame, various types	0	0	0.2	1.5	0	0	10	5	S
						100	100	100	100	
Italy	Masonry - bad quality	1.6	10.1	37.4	100*	13.5	2			RS
	Masonry-medium quality	0	0.6	8.8	73.2*	13.8	2			DS3
	Masonry-good quality	0	0.1	2.4	23	22.1	2.8			DS4
	RC, GLD, <=3 storeys	0	0.5	7.3	54	12.3	1			C3L
	RC, GLD, >=4 storeys	0	1.1	14.3	87.8*	19.5	0.1			C3M
	RC, MSD, <=3 storeys	0	0	0.1	6.4	5.4	0.8			C1L
	RC, MSD, >=4 storeys	0	0	0.2	10.7	4.7	0.1			C1M
						91.3	8.8			
Japan	Unreinforced brick masonry in cement mortar with reinforced concrete floor/roof slabs (9)	0.1	5	20	30			-	-	UFB5
	Confined brick/block masonry with concrete posts/tie columns and beams (10)	-	1	5	20			3	3	RM3
	RC MRF Designed with seismic features (various ages) (15)	-	1	2	10			10	10	C1
	RC MRF Frame with unreinforced masonry infill walls (16)	-	1	5	10			-	-	C3
	RC MRF Flat Slab Structure (17)	-	1	3	15			5	5	C7
	RC MRF Frame with concrete shear walls-dual system (19)	-	-	1	4			10	-	C6
	RC SW Walls cast in-situ (21)	-	-	1	2	30	2	10	5	C2
	STL MRF With cast in-situ concrete walls (24)	-	-	1	2			20	10	S4

	STL MR with lightweight partitions (25)	-	-	1	4			20	10	S3
	STL CBF (26)	-	-	1	4			10	10	S2
	Wooden; Pre-1981	2	5	10	50*	30	50	8	17	W6
	Wooden; Post-1981	-	1	5	15	40	48	4	30	W3
						100	100	100	100	
Macedonia	Rubble (field) stone masonry in mud/lime mortar	5	15	40*	75*	1	5	0	0	RS2
	Mud walls, mud walls with hori. Wood element	5	25	70*	90*	1	5	0	0	M2
	Unreinforced brick masonry in mud mortar	2	12	35	70*	5	15	0	0	UFB1
	Unreinforced brick masonry in lime/cement mortar	1	6	25	50*	5	15	1	5	UFB4
	Confined brick/block masonry with concrete posts/tie columns	0	1	6	10*	20	30	5	40	RM3
	MRF designed for gravity loads	0	2	10	35*	15	5	25	2	C3
	MRF designed for seismic features	0.1	1	4	12	24	5	20	10	C1
	MRF with concrete shear walls-dual system	0	0.2	2	7	24	3	30	5	C6
	Shear wall cast in situ	0	0.1	1	3	5	0	2	0	C2
						100	83	83	62	
Mexico	Earthen/mud/adobe/rammed earthen walls (5)	10*	40*	70*	90*	Very Low	Mode rate	Very Low	Moderat e	A1
	Clay brick/block masonry walls (9)	10*	30*	60*	80*	Low	Mode rate	Very Low	Moderat e	UFB5
	Clay/concrete (confined) (10)	0	5	10	15	High	Mode rate	Moderat e	Moderat e	RM3
	Concrete block masonry (12)	0	10	15	20	Moderat e	Mode rate	Moderat e	Moderat e	UCB
	Moment resisting frame (15)	5	20	40	50*	Low	Very Low	Moderat e	Very Low	C1
	Moment resisting frame (16)	0	10	20	40*	Low	Very Low	Moderat e	Very Low	C3
	Moment resisting frame (17)	10*	30*	60*	80*	Low	Very Low	Moderat e	Very Low	C7

	Moment resisting frame (19)	0	10	15	20	Low	Very Low	Moderate	Very Low	C6
	Moment resisting frame (23)	0	10	30	50*	Very Low	Very Low	Low	Very Low	S5
	Braced frame (26)	0	10	15	30	Very Low	Very Low	Very Low	Very Low	S2
Nepal	Unreinforced earthen/mud/adobe/stone in mud mortar	?	75*	90*	100*	20	43	5	15	RS1
	Unreinforced brick, dressed stone in masonry mud mortar	?	45*	65*	100*	14	26	10	5	DS1
	Unreinforced brick, block, dressed stone masonry in cement sand mortar	?	40*	55*	80*	55	11	30	5	UFB4
	RC frame with unreinforced masonry infill (no asiesmic design and detailing	?	10	25	60*	2	0	20	0	C3
	Wooden, bamboo frame with wattle and daub, wooden planks	?	10	30	70*	9	20	5	10	W5
						100	100	70	35	
New Zealand	Solid clay brick in cement mortar (9)	0	0.0015	0.3	5.4	0.4	0.3	0.8	0.6	UFB4
	Hollow concrete block masonry (12)	0	0.0001	0.015	0.3	1.9	2.1	6.2	5.8	UCB
	RCC frame (14)	0	0.0004	0.08	1.4	0.1	0.1	1.8	1.7	C3
	RCC frame (15)	0	0	0.008	0.14	0.3	0.2	3.9	2.9	C1
	RCC shear wall (19)	0	0.0001	0.02	0.4	2.8	1.8	20.4	11.9	C6
	RCC shear wall (21)	0	0.0001	0.015	0.3	0.9	2.2	5.9	6.7	C2
	Steel frame (25)	0	0.0001	0.015	0.3	0.9	2.2	5.9	6.7	S1

	Light steel frame (26)	0	0	0.006	0.11	0.7	2	3.3	4.6	S3
	Wood stud construction (32)	0	0	0.004	0.07*	91.7	88.9	47.1	54.6	W1
	Buildings with perimeter walls made of large single height (34)	0	0.0004	0.08	1.4	0.3	0.2	4.7	4.5	UNK
						100	100	100	100	
Pakistan	Stone masonry walls	70*	100*	100*	100*	1	10			RS1
	Earthen walls	80*	100*	100*	100*	1	28			M1
	Clay brick masonry walls	30*	80*	100*	100*	1	10			UFB1
	Clay brick masonry walls	5	20	60	100*	25	6			UFB2
	Clay/Concrete	5	15	40	90*	2	0.5			RM3
	Concrete block masonry	20*	80*	100*	100*	10	2			UCB
	Concrete block masonry	5	20	70	100*	1	0			UCB
	RC frame structure with masonry infill walls designed for gravity loads	10	50*	100*	100*	3	0			C3
	Load bearing timber frame	20	70*	100*	100*	0	1			W6
						44	57.5			
Peru	Older moment resisting frame with unreinforced masonry infill walls	0	5	10	40	20				C3
	Modern moment resisting frame with unreinforced masonry infill walls	0	1	5	25	10				C1
	Dual System (Frames with concrete and shear walls)	0	0	3	15	10				C6
	Concrete shear walls cast in-situ	0	0	2	5	10				C2
	Unreinforced clay brick masonry in cement mortar (various floor/room systems)	0	1	5	35	25	10			UFB4
	Confined brick masonry with concrete columns and beams	0	0	3	20	20				RM3
	Earthen buildings	10	30	70*	100*	5	90			M

						100	100			
	Clay brick 1-3 stories for 1-2 family without seismic feature (7)	2.5	40*	70*	85*	20				UFB1
	Clay brick 1-5 stories buildings with seismic feature (10)	0	10	30	60	15				RM2
	Adobe walls (5)	7.5	50*	80*	92.5*	10				A
	Precast wall panel structure with welded connections (22)	0	0	0	0	6				PC4
	Precast wall panel structure with monolithic connections (22)	0	0	0	0	4				PC1
	Walls cast in situ (21)	0	0	0	0	6				C2
Russia	Moment resisting frame precast and cast in situ (18)	1	15	37.5	47.5	4				PC2
	Moment resisting frame with masonry infilling (16)	1	15	37.5	47.5	7				C3
	Moment resisting frame with shear walls (19)	0	0	7.5	15	6				C6
	Small concrete block masonry walls with concrete floors and roof (12)	1.5	17.5*	35*	50*	5				UCB
	Large concrete block walls with reinforced concrete floors and roof (12)	1.5	17.5*	35*	50*	4				UCB
	Timber log building	0	2.5	12.5	20	7				W4
	Wood panel wall buildings (33)	0	2.5	12.5	20	2				W4
						96	0	0	0	
	Rubble stone masonry in mud/lime mortar	0	2	22	90*	5	13			RS1
	Unreinforced clay brick masonry walls in lime/cement mortar with	0	1	7	60*	24	23			UFB2
Slovenia	Confined clay brick masonry walls in lime/cement mortar with	0	0	2	5	30	28			RM3
	Reinforced concrete frames mostly designed for gravity loads only	0	0	7	26	7	3			C3
	Reinforced concrete walls cast in situ	0	0	0	2	11	4			C2
						77	71	0	0	

Spain	Floors and roof slabs made of wood or steel beams with with ceramics vaults in between (7)	1.4	6.7	15		15	23	12	16	UFB1
	Floors and roof slabs made of concrete beams with ceramics vaults in between (9)	1	6	11		31	36	18	18	UFB4
	Waffle slabs or slabs with wide beams; both structures with masonry infill walls (17)	1	2	4		46	38	69	66	
	Slabs are flat slabs (waffle slabs or slabs with wide beams) (23)	0	0.3	1		5	2	1	0	S5
	Walls are not cast in-situ but masonry infill walls (24)	0	0.3	1		2	0	0	0	S4
	With brick masonry infill (31)	0	0.5	1		1	1	0	0	W7
						100	100	100	100	
Switzerland	Undressed stone masonry with timber floors	< 5	5-15	30-60*	50-100*	2	11	1	2	RS1
	Brick/concrete block/massive stone masonry in lime/cement mortar with timber floors	0	< 5	5-15	35-55	5	14	4	3	MS
	Brick/concrete block masonry in cement mortar with reinforced concrete floors	0	< 1	< 5	5-15	5	14	2	2	UCB
	Mixed structure of unreinforced masonry and reinforced concrete (walls of reinforced concrete and unreinforced masonry with rc floors)	0	< 2	2-20	20-40	9	14	4	2	RM3
	Reinforced concrete frames	0	< 1	< 5	5-15	1	0	14	5	C3
	Reinforced concrete walls	0	< 1	< 5	5-15	9	7	11	3	C2
	Reinforced concrete walls and frames	0	< 1	< 5	5-15	1	0	11	5	C6
	Precast concrete	0	< 2	2-10	10-20	0	0	11	3	PC2
	Timber structures	0	0	< 2	< 5	0	11	0	3	W or W7
	Steel structures	0	0	< 1	< 5	0	0	14	5	S
						32	71	72	33	
Thailand	Wooden houses, wooden structures	0	5	40	50	5		1		W3 or W6

	Reinforced concrete houses	0	1	10	50	95		98		C
	Steel structures (factory)	0	0	0	1-2	0	0	1		S
						100	0	100	0	
Turkey1 (P. Gulkan)	Stone Masonry Walls	7.5	25	50	80*	4	15	0	1	DS
	Adobe Block Walls	10	40*	70*	90*	2	15	0	2	A
	Clay brick/block masonry walls	8	22	45	72	25	30	15	35	UFB
	Concrete block masonry	7.5	18	40	65	5	5	15	25	UCB
	Moment resisting frame/frame with un-reinforced masonry infill walls	0.5	2	20	40	40	25	50	35	C3
	Moment resisting frame/flat slabl structure	0.5	2	22	45	8	0	5	0	C7
	Moment resisting frame/frame with concrete shear walls-dual system	0	0.5	5	15	5	0	6	0	C6
	Shear wall structure	0	0.1	1	5	5	0	5	0	C2
	Pre-cast frame structure	2	12	32	60*	2	0	2	1	PC2
	Moment resisting frame	0.1	0.3	3	8	0	0	1	0	S
	Load-bearing timber frame	0.5	2	10	20	4	10	1	1	W6 or W7
						100	100	100	100	
Turkey2 (M. Erdik)	Moment Resisting Frame with URM infill walls (16)	<3	3-8	8-20	20-40	32	18	75	1	C3
	Unreinforced brick masonry in cement mortar with R/C floors (9)	<2	2-5	5-15	15-35	20	2	5	1	UFB5
	Adobe Block Walls (5)	<10	10-35	35-75	75-90*	0	7	0	0	A
	Rubble Stone (1)1	<12	12-45	45-80	80-95*	0	3	0	0	RS
						52	30	80	2	
United Kingdom	Brick masonry, weak (lime) mortar	0	0.6	4	15	35	50	48	50	UFB3
	Brick masonry, cement mortar, timber floors	0	0.1	1	6	63	50	20	35	UFB4

	RC frame, non-seismic but designed for gravity loads	0	0.2	2	11	2	0	21	10	C3
	Steel frame, various types	0	0	0.2	1.5	0	0	11	5	S1
						100	100	100	100	

* These estimates appear to be outside the bounds of EMS-98 based expected range of collapse probability. The EMS based collapse relates to damage grade 5 & fractions in damage grade 4 in EMS scale) for general building class of this type.