WORLD HOUSING ENCYCLOPEDIA
COUNTRY ESTIMATES:
CONSTRUCTION TYPES & SEISMIC VULNERABILITIES

The WHE, with sponsorship from the PAGER project of the U.S. Geological Survey, is embarking on a project to summarize worldwide building inventory and seismic vulnerability. The estimated building inventories are being used in the development of a rapid post earthquake casualty estimation program, Prompt Assessment of Global Earthquakes for Response (PAGER; see http://earthquake.usgs.gov/eqcenter/pager/) at the USGS. The data will also enhance the housing stock distribution and vulnerability data for existing WHE housing reports for different countries, as well as provide the beginning of summary data for countries--see www.world-housing.net).
The estimates are being provided by experts in the various countries, and the completed Excel file for each country or region will be posted and shared online at the WHE website. Over time, the WHE expects these estimates to become more accurate, for more experts to provide data, and for researchers and others to come to view these summary estimates as a credible source of comparable, internally consistent global data.
The WHE project is looking for at least one participant from each country to provide expert judgment. Experts are asked to fill out **the attached Excel file**, providing their best estimate of the predominant building types in their country, estimating the probability of collapse for these building types (a proxy for vulnerability), and for each building type, estimating of the fraction of the urban and rural population who live and work in that type. [A $300 honorarium is available upon completion of this form.]

The Excel file is divided into 3 parts:

Part 1: Contributors' Information
Part 2: Summary of Construction Types, Vulnerability and Population
Part 3: Additional Experts Consulted, Sources, Comments

To assist you in completing the summary of construction types, please refer to the instructions on the next few pages.

Reference Information and Assistance

For assistance in selecting construction types and estimating vulnerability in the Excel file, refer to Tables 1, 2 and 3 below:

Table 1: PAGER Construction Types

The construction types listed in this table correspond to the drop-down menu in the Excel file. If appropriate for your country, use this table of construction types, which have been developed by the PAGER project, building from other classifications (these other classification systems are shown in the right side columns), in selecting the predominant construction types for buildings in your country (including residential and office buildings). If these construction types do not correspond to predominant types in your country, use the blank fields in the Excel file to describe the types in your country.

Material	PAGER-STR	Description	HAZUS Class	WHE-EERI Class	EMS-98	Coburn & Spence 2002	Risk-EU
Wood/Timber	W	Wood			W		W
	W1	Wood stud-wall frame with plywood/gypsum board sheathing. Absence of masonry infill walls. Shear wall system consists of plywood or manufactured wood panels. Exterior is commonly cement plaster ("stucco"), wood or vinyl planks, or aluminum planks (in lower cost houses). In addition, brick masonry or stone is sometimes applied to the exterior as a non-load-bearing veneer. The roof and floor act as diaphragms to resist lateral loading. (US & Canadian single family homes).	W1	32		CT2	
	W2	Wood frame, heavy members (with area > 5000 sq. ft.) (US & Canadian commercial and industrial wood frame).	W2				
	W3	Light post and beam wood frame. The floors and roofs do not act as diaphragms. No bracing, poor seismic load resistance path with poor connections. Timber frame may have partial infill walls with or without timber cladding.		28			
	W4	Wooden panel or log construction. Walls are made of timber logs sawn horizontally in a square or circular cross section and assembled with special end joints. (Typically in central Asia, Russia).		33			
	W5	Walls with bamboo/light timber log/reed mesh and post (Wattle and Daub). (Wattle and Daub- a woven lattice/sticks of wooden strips called wattle is daubed with a sticky material usually made of some combination of wet soil, clay, sand, animal dung and straw).		30		AE2	
	W6	Unbraced heavy post and beam wood frame with mud or other infill material. Un-braced timber frame with connections meant to resist (gravity) vertical loads only. Floors or roof consists of wood purlins supporting thatched roof, wood planks or rafters supporting clay tiles.		29		CT1	
	W7	Braced wood frame with load-bearing infill wall system. Frame is diagonally braced and infill walls are generally made of brick masonry, adobe, or wooden planks or wattle & daub infill. (European style)		31			
Adobe/Mud Walls	M	Mud walls		3			
	M1	Mud walls without horizontal wood elements					
	M2	Mud walls with horizontal wood elements		4			
	A	Adobe blocks (unbaked sundried mud block) walls		5	M2	AA1	M2
	A1	Adobe block, mud mortar, wood roof and floors					
	A2	Adobe block, mud mortar, bamboo, straw, and thatch roof					
	A3	Adobe block, straw, and thatch roof cement-sand mortar					
	A4	Adobe block, mud mortar, reinforced concrete bond					

		beam, cane and mud roof					
	A5	Adobe block, mud mortar, with bamboo or rope reinforcement					
	RE	Rammed Earth/Pneumatically impacted stabilized earth		6		AE1	
Stone/Block Masonry	RS	Rubble stone (field stone) masonry		1	M1		M1.1
	RS1	Local field stones dry stacked (no mortar) with timber floors, earth, or metal roof.		1			
	RS2	Local field stones with mud mortar.		1		AR1	
	RS3	Local field stones with lime mortar.				AR1	
	RS4	Local field stones with cement mortar, vaulted brick roof and floors					
	RS5	Local field stones with cement mortar and reinforced concrete bond beam.					
	DS	Rectangular cut-stone masonry block			M3	BD1	M1.2
	DS1	Rectangular cut stone masonry block with mud mortar, timber roof and floors					
	DS2	Rectangular cut stone masonry block with lime mortar					
	DS3	Rectangular cut stone masonry block with cement mortar					
	DS4	Rectangular cut stone masonry block with reinforced concrete floors and roof					
	MS	Massive stone masonry in lime or cement mortar		2	M4		M1.3
	UCB	Unreinforced concrete block masonry with lime or cement mortar		11	M5	BC1	
Brick Masonry	UFB	Unreinforced fired brick masonry			M5		
	UFB1	Unreinforced brick masonry in mud mortar without timber posts		7			
	UFB2	Unreinforced brick masonry in mud mortar with timber posts		8			M3.1
	UFB3	Unreinforced brick masonry in lime mortar					M3.2
	UFB4	Unreinforced fired brick masonry, cement mortar. Timber flooring, timber or steel beams and columns, tie courses (bricks aligned perpendicular to the plane of the wall)				BB1	M3.3
	UFB5	Unreinforced fired brick masonry, cement mortar, but with reinforced concrete floor and roof slabs		9	M6		M3.4
Reinforced/Confined Masonry	RM	Reinforced masonry				DB1	M4
	RM1	Reinforced masonry bearing walls with wood or metal deck diaphragms					
	RM1L	Reinforced masonry bearing walls with wood or metal deck diaphragms low-rise	RM1L				
	RM1M	Reinforced masonry bearing walls with wood or metal deck diaphragms mid-rise (4+ stories)	RM1M				
	RM2	Reinforced masonry bearing walls with concrete diaphragms					
	RM2L	Reinforced masonry bearing walls with concrete diaphragms low-rise	RM2L				
	RM2M	Reinforced masonry bearing walls with concrete diaphragms mid-rise	RM2M				
	RM2H	Reinforced masonry bearing walls with concrete diaphragms high-rise	RM2H				
	RM3	Confined masonry		10	M7	BB2	M4
Reinforced Concrete	C	Reinforced concrete					
	C1	Ductile reinforced concrete moment frame with or without infill		15	RC3	DC1	RC1
	C1L	Ductile reinforced concrete moment frame with or without infill low-rise	C1L				

	C1M	Ductile reinforced concrete moment frame with or without infill mid-rise	C1M				
	C1H	Ductile reinforced concrete moment frame with or without infill high-rise	C1H				
	C2	Reinforced concrete shear walls		21	RC6		RC2
	C2L	Reinforced concrete shear walls low-rise	C2L				
	C2M	Reinforced concrete shear walls mid-rise	C2M				
	C2H	Reinforced concrete shear walls high-rise	C2H				
	C3	Nonductile reinforced concrete frame with masonry infill walls		16	RC2	DC2	
	C3L	Nonductile reinforced concrete frame with masonry infill walls low-rise	C3L				RC3
	C3M	Nonductile reinforced concrete frame with masonry infill walls mid-rise	C3M				
	C3H	Nonductile reinforced concrete frame with masonry infill walls high-rise	C3H				
	C4	Nonductile reinforced concrete frame without masonry infill walls		14	RC1	CC1	
	C4L	Nonductile reinforced concrete frame without masonry infill walls low-rise					
	C4M	Nonductile reinforced concrete frame without masonry infill walls mid-rise					
	C4H	Nonductile reinforced concrete frame without masonry infill walls high-rise					
	C5	Steel reinforced concrete (Steel members encased in reinforced concrete)				DH1	S5
	C5L	Steel reinforced concrete (Steel members encased in reinforced concrete) low-rise					
	C5M	Steel reinforced concrete (Steel members encased in reinforced concrete) mid-rise					
	C5H	Steel reinforced concrete (Steel members encased in reinforced concrete) high-rise					
	C6	Concrete moment resisting frame with shear wall - dual system		19		DC3	RC4
	C6L	Concrete moment resisting frame with shear wall - dual system low-rise					
	C6M	Concrete moment resisting frame with shear wall - dual system mid-rise					
	C6H	Concrete moment resisting frame with shear wall - dual system high-rise					
	C7	Flat slab structure		17			
Precast Concrete	PC1	Precast concrete tilt-up walls	PC1				RC5
	PC2	Precast concrete frames with concrete shear walls		18		DP2	RC6
	PC2L	Precast concrete frames with concrete shear walls low-rise	PC2L				
	PC2M	Precast concrete frames with concrete shear walls mid-rise	PC2M				
	PC2H	Precast concrete frames with concrete shear walls high-rise	PC2H				
	PC3	Precast reinforced concrete moment resisting frame with masonry infill walls				DP1	
	PC3L	Precast reinforced concrete moment resisting frame with masonry infill walls low-rise					
	PC3M	Precast reinforced concrete moment resisting frame with masonry infill walls mid-rise					
	PC3H	Precast reinforced concrete moment resisting frame with masonry infill walls high-rise					
	PC4	Precast panels (wall panel structure)		22		DP3	
Stee	S	Steel			S		
	S1	Steel moment frame		25		DS2	S1

	S1L	Steel moment frame low-rise	S1L				
	S1M	Steel moment frame mid-rise	S1M				
	S1H	Steel moment frame high-rise	S1H				
	S2	Steel braced frame		26		DS4	S2
	S2L	Steel braced frame low-rise	S2L				
	S2M	Steel braced frame mid-rise	S2M				
	S2H	Steel braced frame high-rise	S2H				
	S3	Steel light frame	S3			DS1	
	S4	Steel frame with cast-in-place concrete shear walls		24		DS5	S4
	S4L	Steel frame with cast-in-place concrete shear walls low-rise	S4L				
	S4M	Steel frame with cast-in-place concrete shear walls mid-rise	S4M				
	S4H	Steel frame with cast-in-place concrete shear walls high-rise	S4H				
	S5	Steel frame with unreinforced masonry infill walls		23		DS3	S3
	S5L	Steel frame with unreinforced masonry infill walls low-rise	S5L				
	S5M	Steel frame with unreinforced masonry infill walls mid-rise	S5M				
	S5H	Steel frame with unreinforced masonry infill walls high-rise	S5H				
Other	MH	Mobile homes	MH				
	INF	Informal constructions. (Generally made of wood/plastic sheets/GI Sheets/light metal or composite etc not confirming to engineering standards, commonly in slums, squatters).					
	UNK	Not specified (unknown/default)					

Table 2: Sources of Data

Use this table to see if there might be data for your country to help in the estimates. These are countries for which housing census data has been identified (to date). Click on the Link below to get to these files. If you know of additional sources and/or additional countries, please list them in Part 3 of the Excel file.

Name of Country	Source of Data and WebLink	Name of File [LINK TO ALL THESE FILES: **http://www.eeri.org/clearinghouse/PAGER/** [right click and choose Open Hyperlink to view]
Romania	Housing Census Romania http://www.insse.ro/cms/files/RPL2002INS/vol5/tablesdwellings.htm	Romania Resid Bldgs by Type.pdf
United States	US Census Bureau and Dept of Energy Databook http://www.census.gov/popest/housing/HU-EST2005-4.html	USA_2006 Buildings Energy Data Book.pdf
Pakistan	Pakistan Population Census Organization http://www.statpak.gov.pk/depts/pco/statistics/other_tables/housing_units_by_construction_material.pdf	housing_units_by_construction_material.pdf ; Pakistan_housing_units_by_rooms.pdf
Philippines	Natiaonal Statistics Office http://www.nscb.gov.ph/secstat/d_popn.asp	Philippines_Construction Material.bmp
Nepal	Nepal Census Bureau of Statistics http://www.worldbank.org/html/prdph/lsms/country/nepal2/docs/NLSS%20II%20Report%20Vol%201.pdf	Nepal Living Standards Report.pdf ; Nepal-by construction material.bmp ; Nepal-by roof material.bmp
Japan	Statistical Bureau of Japan http://www.stat.go.jp/english/data/jyutaku/1503.htm	Japan_Housing by Construction Material.xls
Thailand	National Statistics Office Thailand http://web.nso.go.th/pop2000/indiregion/wholetab4.htm	Thailand_Const_Material.bmp

Netherlands Antilles & other territories	Central Bureau of Statistics http://www.cbs.an/census/antl3.asp	Netherland_2001_Housing Census_Data.pdf
Mauritius	National Census Bureau http://www.gov.mu/portal/sites/ncb/cso/ei411/housing.pdf	Mauritius_census-results.pdf
Canada	Statistics Canada http://www12.statcan.ca/english/census01/Products/standard/themes/DataProducts.cfm?S=1&T=40&ALEVEL=2&FREE=0	Canada_2001_Census Data Products.pdf
Finland	Statistics Finland http://www.stat.fi/tk/he/vaestolaskenta/vaestolask_tietohist_en.html	Finland_Household-dwelling-units.pdf
Solomon Island	National Statistics Office http://www.spc.int/prism/country/sb/stats/Censuses%20and%20Surveys/Census99.htm	Solomon_Island_wall.pdf ; Solomon_Island_Construction Material.pdf ; Solomon_Island_floor.pdf
Mexico	Housing Study Report http://www.jchs.harvard.edu/publications/international/SOM_97.pdf	Mexico_construction.bmp
Botswana	Census of Housing http://www.cso.gov.bw/html/about/popn_info.html	Botswana_Housing_Census.pdf
China	National Bureau of Statistics of China http://www.stats.gov.cn/tjsj/ndsj/2006/indexeh.htm	China_Statistical_Year_Book.pdf
Ireland	Central Statistics Office Ireland http://www.cso.ie/census/Census2006_Principal_Demographic_Results.htm	Ireland_PDR 2006 Tables 31-40.pdf
India	Census of India http://www.censusindia.net/2001tables/list_housingtables.html	India_List of Housing Tables _ 2001 Census.pdf
Austria	Statistics Austria http://www.statistik.at/cgi-bin/jahrbuch_2007.pl?KAPITEL=12&SPRACHE=E	Statistics Austria - Statistical Yearbook.pdf
Anguilla	Statistics Department, Ministry of Finance http://www.gov.ai/statistics/census/images/Housing%20and%20Households.pdf	Anguilla Housing and Households.pdf page 25 – 27
Argentina	National Institute of Statistics and Census http://www.indec.mecon.ar/indec/ingles/iu030308.xls	Argentina Housing Statistics (CALMAT).xls
Armenia	Ministry of Statistics http://docs.armstat.am/census/pdfs/B2.pdf	Armenia Housing Construction.pdf
Bolivia	National Institute of Statistics http://www.ine.gov.bo/BEYOND/TableViewer/tableView.aspx?ReportId=245	Bolivia Housing Construction.pdf
Belarus	Ministry of Statistics http://belstat.gov.by/homep/en/census/p19.php	Belarus POPULATION CENSUS 1999.pdf

In making your estimates

Incompleteness is accepted. If you do not know some of the answers please indicate so with a dash ----- or ?. Use 0 only when you know the number or percent IS 0.

To estimate collapse potential

The definition of the probability of collapse should be consistent with the definition provided by EMS-98 and other macroseismic intensity scales rather than by analytical procedures of vulnerability assessment. For example, HAZUS provides a procedure to estimate the collapse proportion of the total square footage of a structure type using a complete damage state fragility curve and a factor P_c which represents probability of collapse given the structure has experienced a complete damage state (FEMA, 2006). In EMS-98, the collapse state is associated with Damage Grade 5 and for each shaking intensity level, the scale defines the damage probability ranges (described in terms of 'few', 'many' and 'most' which approximately indicate 0-15 %, 15-55 % and 55-100% respectively) of a particular vulnerability class. The EMS-98 collapse definition is limited to European observations and is applicable specifically to the European building stock; however, the consistency among EMS-98 and MSK, and MMI, make such definitions sufficiently general to be applicable for the scope of the WHE-PAGER project. Similarly the European construction types within EMS are sufficiently general and does represents most common building stock in many parts of the world.

The concept of collapse is itself ambiguous and is prone to different interpretation depending on the nature of the study. In order to clarify what is intended by the term 'collapse' in this context, specifically concerning causation of casualties, the following set of definitions will be included in the guidelines. These are specified by structural typology, focusing on the structural elements whose failure leads to partial or total collapse of the building (and thus casualties).

- Adobe Structures:
  Collapse of a roof or floor due to loss of support from walls either due to in-plane or out of plane failure.
- Wood Structures:
  Collapse of a particular floor or complete failure of part of the timber-framed structure.
- Masonry Structures:
  Collapse of one or more exterior walls resulting in partial or complete collapse of roof/floor.
- Concrete Structures:
  Collapse of a particular floor or complete failure of part of the framed structure.
- Steel Structures:
  Structure experiences collapse of roof or floor due to instability of steel frame. In case of light frame, this might be due to excessive strain or failure of the brace rods or loss of continuity at connections. In case of braced frame, this is due to failure of most of the critical members which includes lateral braces and moment resisting connections. In case of steel frames with infill, collapse is characterized by failure of critical framed members and failure of most infill walls.
- Precast Concrete Frames:
  Collapse of a particular floor or complete failure of part of the framed structure due to loss of connections or failure in critical members of the frame. Excessive displacement of large span simply supported beams or girders resting on columns may cause failure of intermediate spans or entire roofing system.
- Tiltups:
  Weak diaphragm-to-wall anchorage results in the wall panels falling and the collapse of the supported diaphragm (or roof) (FEMA 154).

Predefined ranges of collapse proportions

Although EMS-98 groups structures of different typologies into the same vulnerability classes, and damage of a certain level given a specified intensity is associated to the vulnerability class and not to the structure type; it is clear that such definitions can be disaggregated and collapse rates can be assigned to each structure type for a given intensity. This has been done for each of the PAGER structure generic classes, predefining the expected proportion of collapses estimated using structure dependent description of damage within EMS intensity scale. Experts should use these predefined ranges only as a guidance to understand the expected behavior of these structure types. Experts are expected to modify the range of collapse probability for the chosen structure type for each intensity level. This change could be a) shifting the expected range beyond the predefined limit, b) widening or narrowing the predefined limits or c) doing both. Experts should explain why they chose to differ from the predefined ranges provided. For example, buildings with vertical/horizontal irregularities (buildings on slopes or buildings with irregular plans), presence or absence of soft story, code era, known structural deficiencies (ductile detailing practice, significant changes in the code provisions during the revisions etc.) may significantly alter the performance of a structure types. Experts should provide such details and wherever possible, should substantiate their opinions through experimental data, published literature or statistics on performance during past earthquakes. The ranges are included in table 3 shown below.

Table 3. Expected range of collapse probability (combination of EMS-98 Grade 4* and 5 damage states) as a function of EMS shaking intensities for various structure types.

Structure Type	EMS Class	EMS Most Likely Vul. Class	Probability of Collapse at Intensity			
			VI	VII	VIII	IX
Rubble stone, field stone	M1	A	0 %	0 to 5 %	2.5 to 32 %	21.25 to 70 %
Adobe (earth brick)	M2	A	0 %	0 to 3.8 %	1.9 to 25 %	17 to 61 %
Simple stone (dressed)	M3	B	0 %	0 to 0.3 %	0.13 to 6.5 %	3.5 to 34 %
Massive stone	M4	C	0 %	0 %	0 to 1.3 %	0.6 to 12 %
Unreinforced brick	M5	B	0 %	0 to 0.3 %	0.13 to 6.1 %	3.3 to 33 %
Unreinforced brick with RC floor	M6	C	0 %	0 %	0 to 1.3 %	0.6 to 12 %
Reinforced or confined masonry (assuming 5 % in B, 50 % in C and 45 % in D)	M7	D	0 %	0 %	0 to 0.3 %	0.1 to 4 %
Reinforced concrete frame without ERD	RC1	C	0 %	0 to 0.3 %	0.13 to 2.6 %	1.6 to 13.4 %
Reinforced concrete frame with moderate ERD	RC2	D	0 %	0 %	0 to 0.25 %	0.15 to 2.6 %
Reinforced concrete frame with high ERD	RC3	E	0 %	0 %	0 %	0 to 0.25 %
Reinforced conc. shear walls without ERD	RC4	C	0 %	0 %	0 to 0.25 %	0.13 to 5.1 %
Reinforced conc. shear walls with moderate ERD	RC5	D	0 %	0 %	0 %	0 to 0.25 %
Reinforced conc. shear walls with high ERD	RC6	E	0 %	0 %	0 %	0 %
Steel frame (all type)	S	E	0 %	0 %	0 to 0.5 %	0.25 to 4.5 %
Timber structures (all type as per)	W	D	0 %	0 %	0 to 0.25 %	0.13 to 2.6 %
Timber structures (high ERD)	WA	-	0 %	0 %	0 %	0 %
Timber structures (medium ERD)	WB	-	0 %	0 %	0 to 0.25 %	0.13 to 2.6 %
Timber structures (low ERD)	WC	-	0 %	0 to 0.3 %	0.13 to 5 %	3 to 27 %

* 25% of Grade 4 are assumed to be collapse causing casualties and hence included in collapse probability estimation.

The following assumptions have been made in deriving the above range:

Description	Quantity (Grade 5)	Quantity (Grade 4)
Few	0 to 15-20 %	0 to 5 %
Many	10-15 to 50-60 %	2.5 to 15 %
Most	50-60 to 100%	12.5 to 25 %

To estimate urban and rural:

For the purpose of this project, URBAN means at least 400 people per km^2, whereas RURAL means fewer (less than 400 people per km^2).

To estimate fractions who live and work in these buildings:

Check this link to see if this table has data for your country-- http://www.eeri.org/clearinghouse/PAGER/UN-compilation.xls (right click on link and select Open Hyperlink)

And/or use Table 3 below for guidance in estimating these fractions.

Table 4: Definitions of fractions of population

VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
<1%	1—10%	10—30%	30—60%	60—100%

If at all possible, we would like column subtotals in the Excel file for columns 4 and 5 to equal 67% or greater, so that we have a fairly representative understanding of building types in your country. Columns 6 and 7 are referring to fractions of the WORKING population; again it would be helpful if the percentages in these two columns equal 67% or greater.

To estimate peak average number of occupants per building:

Estimate an average number of people who might be in such a building type. You can give this as a range if you prefer. If there is a substantial difference between day and night occupancy, please indicate this, by noting *day* and *night* after the number.

Honorarium

A USD 300 honorarium is available upon completion of this form. If you would like the honorarium, please indicate so in the e-mail to Marjorie Greene (mgreene@eeri.org) when you return the Excel file. You must include your mailing address.

If you have any questions on the Excel file or these instructions you can contact Marjorie at the above e-mail address.