Summary of WHE-PAGER Survey (Phase I, II & III)

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EERI Meeting
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WHE-PAGER (Phase I)

- Carried out during Aug 2007- Dec 2008
- Covered 26+ countries
- Emphasis on both inventory and empirical collapse vulnerability data on global building types
- Experience and lessons learnt during Phase I were extremely useful in refining the efforts for Phase I extension (added Taiwan, Morocco, Argentina, Georgia, Romania)

WHE-PAGER (Phase I)

- An analysis document was prepared that summarizes the Phase I efforts and shows some analysis of Phase I data
- A guideline document was prepared for use by future participants (Credit: Dina)
- Modified definition of Collapse (masonry vs. framed construction), Intensity instead of PGA based vulnerability
- Illustration of collapse fragility estimated using definition of EMS intensity scale
- A new survey questionnaire was prepared using PAGER-STR with some modifications to original questionnaire (Credit: Marjorie)

PAGER-STR

Total: 103 types

Label	Description	Detailed Classification (Based on A PAGER Inventory database 2008)
W	Wood (1 + 7)	W1 (Wood with stucco, veneer), W2 W5 (Wattle & Daub), W6 (Unbraced
S	Steel (1+ 17)	S1 (Steel moment frame of low, mid of low, mid and high rise), S5 (Steel
C	Reinforced Concrete (1 + 25)	C1 (Ductile RC moment frame of lov rise), C4 (Nonductile RC frame with
RM	Reinforced Masonry (1+ 8)	R1 (Reinforced masonry bearing wal rise)
MH	Mobile Homes (1)	Mobile homes
M	Mud (1 + 2)	M1 (Mud wall without wood), M2 (M
A	Adobe (1 + 5)	A1 (Adobe mud mortar with wood rc A5 (Adobe with reinforcement)
RE	Rammed Earth (1)	Rammed earth construction
RS	Rubble (Field) Stone (1 + 5)	RS1 (Rubble stone without mortar), I stone with concrete bond beam)
DS	Dressed Stone, blocks (1 + 4)	DS1 (Stone block with mud mortar),
UFB	Unreinforced Fire Brick (1 + 5)	UFB1 (Unreinforced brick with mud and wood diaphragm), UFB4 (Unreir
UCB	Unreinforced Concrete Block (1)	Unreinforced concrete block construc
MS	Massive Stone (1)	Massive stone masonry construction
PC	Precast (10)	PC1 (Precast concrete tilt up walls), I
INF	**Informal (1)**	**Informal constructions (Plastic, po**
UNK	**Unknown (1)**	**Unknown (Missing / Default catego**

Appendix 2. PAGER Structure Type (PAGER-STR):

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			

WHE Survey Questionnaire

Completed by: SUN Bait

Table 1: Summary of Building Types,

WHE Construction Type refer to Table 2 for suggested category(ies) (1)	Description of constr type (refer to Tables 2 and suggested categories sources of data to help this question) (2)
Masonry	Stone Masonry Walls
	Earthen/Mud/Adobe/ d Earthen Walls,(4)(5)
	Clay brick/ block masonry walls (South part)*
	Clay brick/ block masonry walls (North part)*
	Clay brick/ block masonry wall (South part)*
	Clay brick/ block masonry wall (North part)*
	Concrete block mas
Structural concrete	Moment resisting fra
	Moment resistin

WHE-PAGER PROJECT: BUILDING CONSTRUCTION VULNERABILITY AND INVENTORY

This form is divided into 3 parts:

Part I:	**Contributors' Information**
Part II:	**Summary of Construction Types, Vulnerability and Population**
Part III:	**Colleagues Consulted, Additional Sources of Information Used**

PART I: Contributors' Information

1. Country or Region (if you are only responding for part of a country, please indicate which geographic region.
Note: the WHE strongly prefers national estimates, unless you have data that clearly apply to only one region):

2. Name(s) of Contributors

3. Affiliation (Organization)

4. Mailing address (include city and country)

5. E-mail

6. Your self-rating of expertise or confidence: On a scale of 1=low and 5=high, please estimate your level of expertise:

7. Referred intensity scale: (MMI/EMS/MSK). If other scale is referred, please specify mapping

Part II: Summary of Construction Types, Vulnerability and Population

	Construction Material (choose from drop-down list)	Construction Subtype (Choose from drop-down list)	Probability of collapse (%) of building type when subjected to the specified shaking intensity				Fraction of population who LIVE in this building type		Fraction of population who WORK in this building type		Peak average # of occupants per building
			MMI-IX MSK-IX EMS-IX	MMI-VIII MSK-VIII EMS-VIII	MMI-VII MSK-VII EMS-VII	MMI-VI MSK-VI EMS-VI	Urban	Rural A	Urban	Rural	
1	Wood/Timber										
2											
3											
4											
5											
6											

Drop-down list:
- Wood
- Wood stud-wall frame with plywood/gypsum board sheathing
- Wood frame, heavy members (with area > 5000 sq. ft.)
- Light post and beam wood frame
- Wooden panel or log construction
- Walls with bamboo/light timber log/reed mesh and post (Wattle and Daub)
- Unbraced heavy post and beam wood frame with mud or other infill material
- Braced wood frame with load-bearing infill wall system

Form

EMS-based Collapse Vulnerability

Structure Type	Class	Probability of Collapse at EMS Intensity			
		VI	VII	VIII	IX
Rubble stone, field stone	M1	0 %	0 to 5 %	2.5 to 32 %	21.25 to 70 %
Adobe (earth brick)	M2	0 %	0 to 3.8 %	1.9 to 25 %	17 to 61 %
Simple stone (dressed)	M3	0 %	0 to 0.3 %	0.13 to 6.5 %	3.5 to 34 %
Massive stone	M4	0 %	0 %	0 to 1.3 %	0.6 to 12 %
Unreinforced brick	M5	0 %	0 to 0.3 %	0.13 to 6.1 %	3.3 to 33 %
Unreinforced brick with RC floor	M6	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	0 %	0 %	0 to 0.3 %	0.1 to 4 %
Reinforced concrete frame without ERD	RC1	0 %	0 to 0.3 %	0.13 to 2.6 %	1.6 to 13.4 %
Reinforced concrete frame with moderate ERD	RC2	0 %	0 %	0 to 0.25 %	0.15 to 2.6 %
Reinforced concrete frame with high ERD	RC3	0 %	0 %	0 %	0 to 0.25 %
Reinforced shear walls without ERD	RC4	0 %	0 %	0 to 0.25 %	0.13 to 5.1 %
Reinforced shear walls with moderate ERD	RC5	0 %	0 %	0 %	0 to 0.25 %
Reinforced shear walls with high ERD	RC6	0 %	0 %	0 %	0 %
Steel frame (all type)	S	0 %	0 %	0 to 0.5 %	0.25 to 4.5 %
Timber structures (all type as per EMS)	W	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 %

Credit: Kishor Jaiswal and Dina D’Ayala

Strategy for Review

- Revisit Phase I data, Identify suspect \ contributions and go back to experts to seek possible revisit- **Did not work !**

- Provide the guideline, analysis document and suspect contribution to Steering Committee and seek their recommendations- **Could not make progress !**

- Provide all the data on web (but with asterisk marked). Meanwhile we selected contributions which are "reasonable" for a selected PAGER STR for implementation- Proxy in absence **!**

Selected Collapse Fragility Functions

Appendix A

Following table provides the list of collapse fragility functions by PAGER structure type used for semi-empirical model.

PAGER Structure Type	Collapse Probability MMI 6.0	MMI 6.5	MMI 7.0	MMI 7.5	MMI 8.0	MMI 8.5	MMI ≥ 9.0	WHE Country Expert	Building Class Description by WHE Experts
A, A1, A2, A3, A4, A5, INF	0	0.05	0.1	0.325	0.55	0.7	0.85	Chile	Adobe
C1, C	0	0.005	0.01	0.015	0.02	0.06	0.1	Japan	RC MRF Designed with seismic features (various ages)
C1L	0	0	0	0.0005	0.001	0.0325	0.064	Italy	RC, MSD, <=3 storeys
C1M, C1H	0	0	0	0.001	0.002	0.0545	0.107	Italy	RC, MSD, >=4 storeys
C2	0	0	0	0	0	0.01	0.02	Slovenia	Reinforced concrete walls cast in situ
C2L, C2M, C2H	0	0	0	0.005	0.01	0.015	0.02	Japan	RC SW Walls cast in-situ
C3, C3L, C3M, C3H, C4, C4L, C4M, C4H, C5, C5L, C5M, C5H	0	0.001	0.002	0.011	0.02	0.065	0.11	United Kingdom	RC frame, non-seismic but designed for gravity loads
DS2, DS, DS1, DS3, DS4	0	0.005	0.01	0.0675	0.125	0.2875	0.45	Germany	Stone masonry walls
M, M1, M2	0.05	0.15	0.25	0.475	0.7	0.8	0.9	Macedonia	Mud walls, mud walls with hori. Wood element
MS	0	0.0125	0.025	0.0625	0.1	0.275	0.45	Switzerland	Brick/concrete block/massive stone masonry in lime/cement mortar with timber floors
PC1, PC2, PC2L, PC2M, PC2H, TU	0	0.005	0.01	0.035	0.06	0.105	0.15	Switzerland	Precast concrete
RM, RM1, RM1L, RM1M	0	0.005	0.01	0.06	0.11	0.205	0.3	Switzerland	Mixed structure of unreinforced masonry and reinforced concrete (walls of reinforced concrete and unreinforced masonry with rc floors)
RM2	0	0.005	0.01	0.03	0.05	0.125	0.2	Japan	Confined brick/block masonry with concrete posts/tie columns and beams
RM2L, RM2M, RM2H	0	0.025	0.05	0.125	0.2	0.25	0.3	Chile	Partially reinforced or confined masonry (Hybrid masonry)

Empirical Collapse Vulnerability

If the collapse fragility is expressed as:

$$[Y] = [y_1,\ y_2,\ \ y_3 \ldots\ldots\ldots\ldots y_n] \quad \text{at} \quad [X] = [x_1,\ x_2,\ \ x_3 \ldots\ldots\ldots\ldots x_n]$$

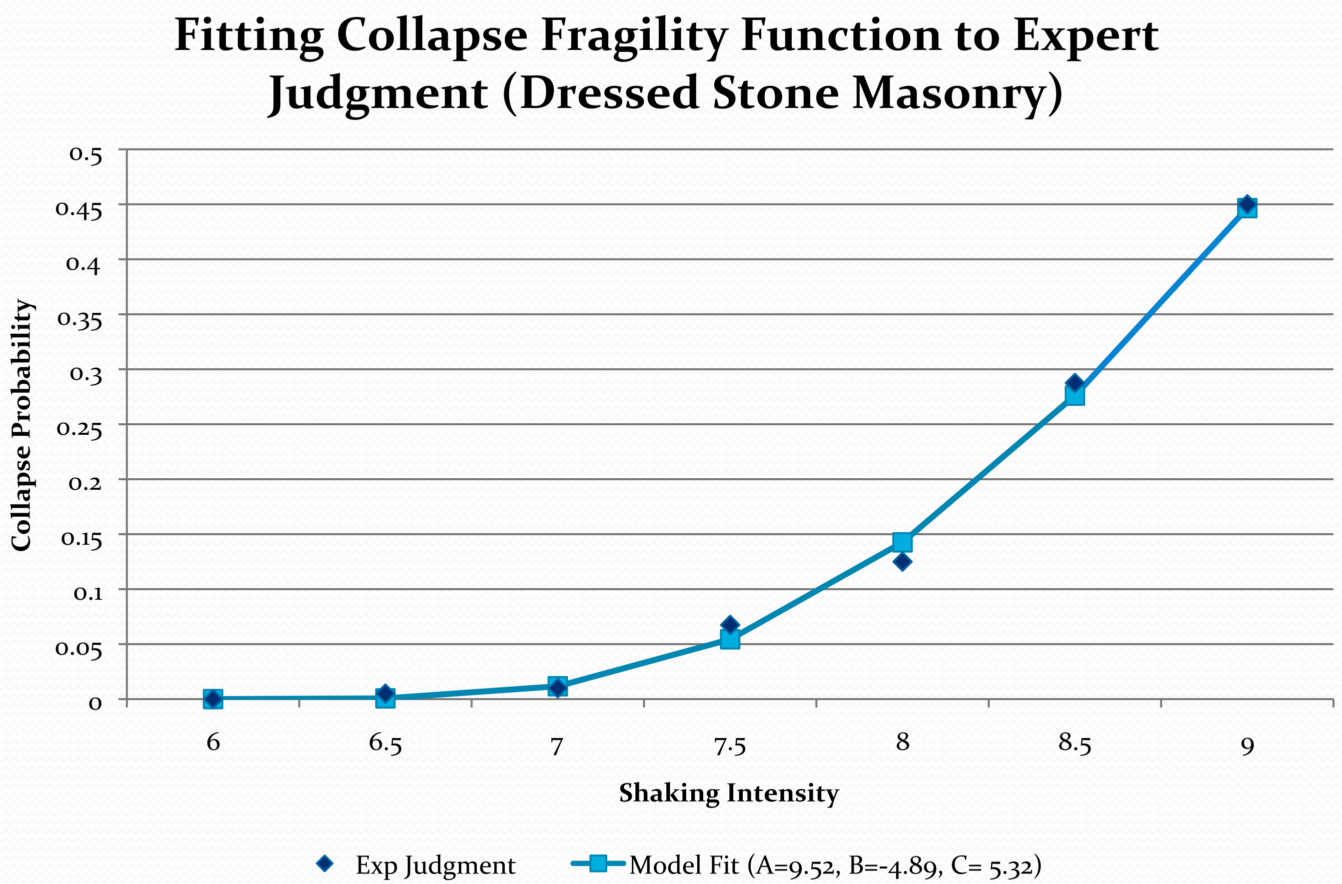
The collapse fragility defined in terms of shaking intensity S is given as:

$$CR_j(S) = A_j \times 10^{\left(\frac{B_j}{S - C_j}\right)} \qquad R^2 = 1 - \frac{\text{var}[y - F]}{\text{var}[y]}$$

The total estimated fatalities E[*L*] over n grid cells as:

$$E[L] \approx \sum_{i=1}^{n} \sum_{j=1}^{m} P_i . f_{ij} . CR_j(S_i) . FR_j$$

Empirical Collapse Vulnerability



Empirical Collapse Vulnerability

PAGER Structure Type	Collapse Fragility Parameters			
	A	*B*	*C*	*R^2*
A, A1, A2, A3, A4, A5, INF	10.76	-5.34	4.05	0.91
C1, C	8.85	-8.83	4.46	0.89
C1L	4.81	-5.62	5.99	0.88
C1M, C1H	8.04	-5.66	5.97	0.89
C2	1.95	-6.14	5.90	0.89
C2L, C2M, C2H	0.44	-6.10	4.40	0.91
C3, C3L, C3M, C3H, C4, C4L, C4M, C4H, C5, C5L, C5M, C5H	3.42	-5.03	5.62	0.93
DS, DS1, DS2, DS3, DS4	9.52	-4.89	5.32	0.95
M, M1, M2	2.56	-1.69	5.18	0.94
MS	11.92	-5.06	5.44	0.92
PC1, PC2, PC2L, PC2M, PC2H, TU	0.85	-2.35	5.90	0.95
RM, RM1, RM1L, RM1M	4.00	-4.20	5.27	0.97
RM2	4.47	-4.88	5.38	0.93
RM2L, RM2M, RM2H	0.90	-1.60	5.63	0.96
RS, RS1, RS2, RS3, RS4, RS5	6.17	-4.58	5.03	0.89

PAGER Structure Type	Collapse Fragility Parameters			
	A	*B*	*C*	*R^2*
S, S1L, S1M, S1H	0.85	-6.06	5.54	0.93
S1	0.45	-8.71	4.40	0.80
S2, S2L, S2M, S2H	3.14	-8.38	4.57	0.95
S3	0.36	-9.96	5.03	0.89
S4, S4L, S4M, S4H	0.44	-6.10	4.40	0.91
S5, S5L, S5M, S5H	2.31	-7.14	5.72	0.87
UCB	2.15	-5.18	5.11	0.95
UFB, RE, UNK	3.88	-4.22	4.97	0.94
UFB1	15.69	-7.62	3.35	0.98
UFB2	19.38	-4.54	5.98	0.92
UFB3	8.03	-7.59	4.60	0.95
UFB4	12.63	-5.82	5.64	0.92
W	0.49	-2.14	5.87	0.95
W1, MH	1.30	-6.40	4.92	0.95
W2	0.86	-2.05	5.76	0.95
W3, W4	0.67	-1.69	5.72	0.96

Fragility Function Calibration

If the collapse fragility (observations/judgment) is expressed as: $[Y] = [y_1, y_2, y_3 \ldots\ldots\ldots y_n]$

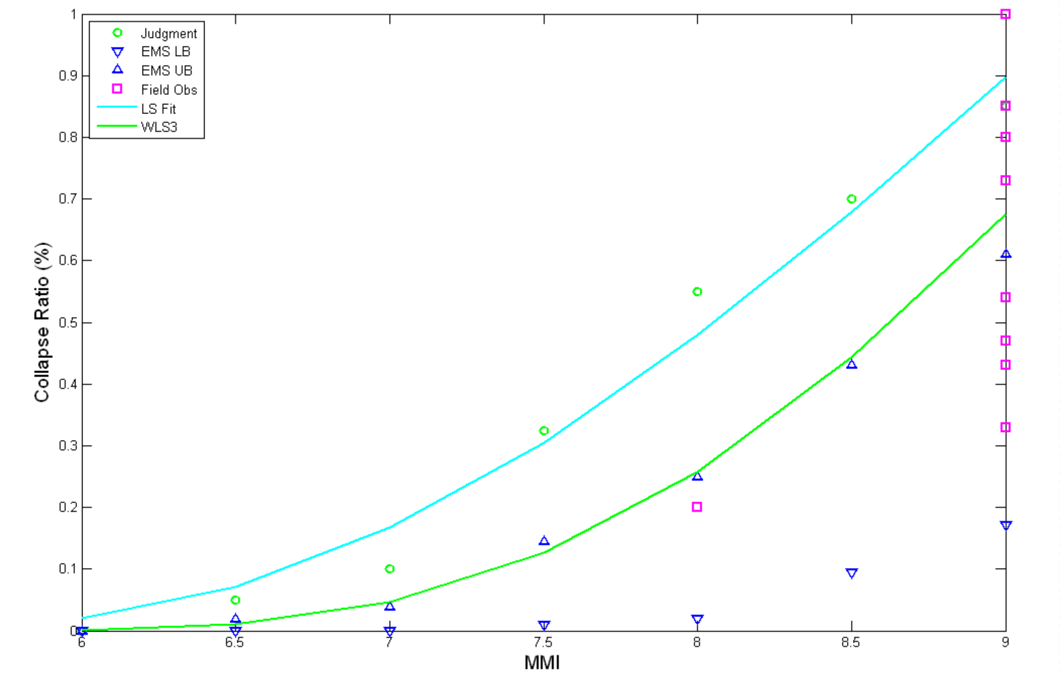
at shaking intensity $[X] = [x_1, x_2, x_3 \ldots\ldots\ldots x_n]$ with weights

$$[W] = [w_1, w_2, w_3 \ldots\ldots\ldots w_n]$$

Minimization Approach-

$$\varepsilon^2 = \sum_i w_i * \left[Y_i - F(x_i)\right]^2$$

This approach can be used to update the collapse fragility functions when collapse data for past earthquakes is available

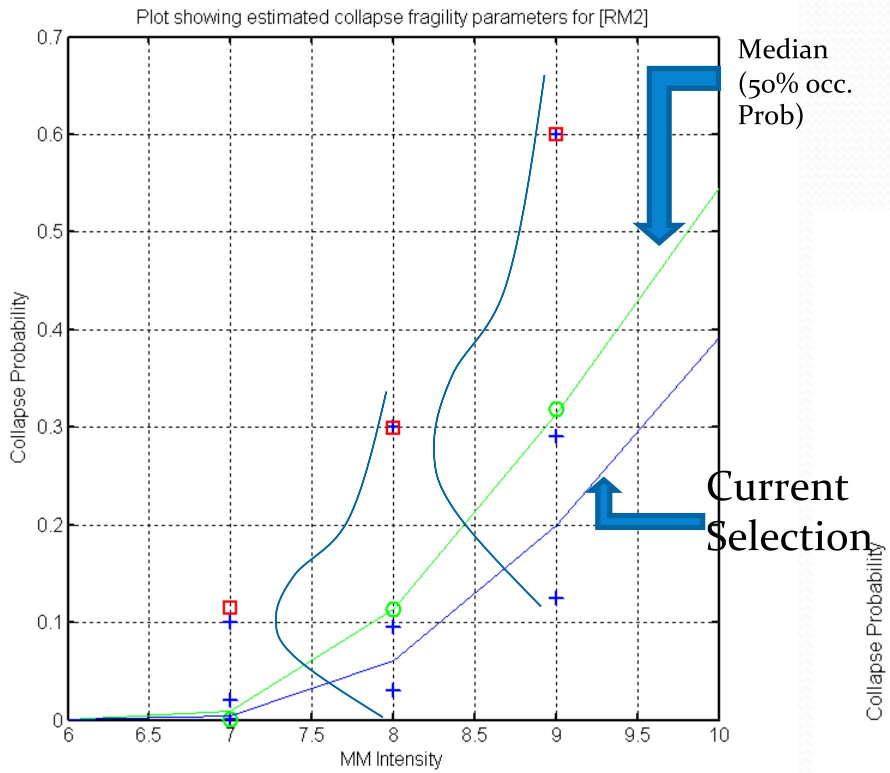


UCAM Databa

surveyid	numbersurveyed	buildingclass	damagelevel	placename
4126	12057	W	No damage	Fukui City (
4129	12425	W	Total collapse	Fukui City (
4137	6713	W	Total collapse	Yoshida Gu
4156	35	W	Half collapse	Noumi Gur
4159	0	W	Burned	Kahoku Gu
4162	12675	W	No damage	Komatsu C
4183	5	RC	B	Niigata
4199	4	RC	F	Akita
4172	3018	W	Total collapse	Niigata
4209	330	W+Mortar	D2	Sendai City
4212	2	W+Mortar	D5	Sendai City
4220	0	Block	unknown	Sendai City
4223	118	RC+SRC	D2	Sendai City
4226	1	RC+SRC	D5	Sendai City
4224	10	RC+SRC	D3	Sendai City
4227	5	RC+SRC	unknown	Sendai City
4235	10	unknown	D0	Sendai City
4238	1	unknown	D3	Sendai City
4241	1	unknown	unknown	Sendai City
4202	1059	W	D2	Sendai City
4210	44	W+Mortar	D3	Sendai City
4213	11	W+Mortar	unknown	Sendai City
4216	7	Block	D2	Sendai City
4219	1	Block	D5	Sendai City
4222	262	RC+SRC	D1	Sendai City
4230	18	S	D2	Sendai City
4233	0	S	D5	Sendai City
4236	5	unknown	D1	Sendai City

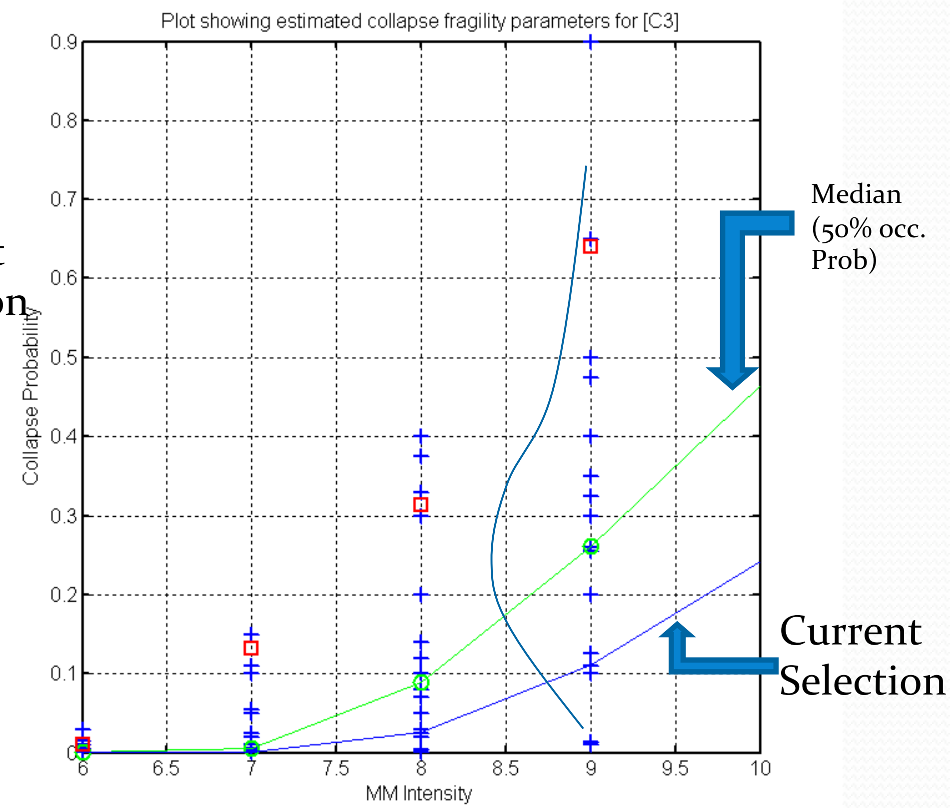
EQ Name	Date	No. of Observations
Aegean	15/06/1995	67
Athens	07/09/1999	36
Bhuj	26/01/2001	24
Boumerdes	21/05/2003	42
Chi-Chi	21/09/1999	1890
Erzincan	13/03/1992	123
Fukui	28/06/1948	44
Fukuoka-ken Seiho-oki	20/03/2005	66
Geiyo	24/03/2001	55
Hokkaido Nansei-oki	12/07/1993	140
Irpinia	23/11/1980	3234
Kalamata	13/09/1986	32
Kobe	17/01/1995	598
Kocaeli	17/08/1999	438
Kushiro-oki	15/01/1993	32
Lefkada	14/08/2003	3510
Manjil	21/06/1990	64
Miyagi-ken	12/06/1978	42
Miyagi-ken Hokubu	26/07/2003	65
Newcastle	27/12/1989	40
Niigata	16/06/1964	30
Niigata-ken Chuetsu	23/10/2004	170
Northridge	17/01/1994	720
Roermond	13/04/1992	666
Sanriku-Haruka-Oki	28/12/1994	24
Spitak	07/12/1988	368
Tipaza	29/10/1989	27
Tottori-ken Seibu	06/10/2000	102
Wenchuan	12/05/2008	30
Total		12679

Fitting Beta Distribution for Uncertainty



Reinforced Masonry

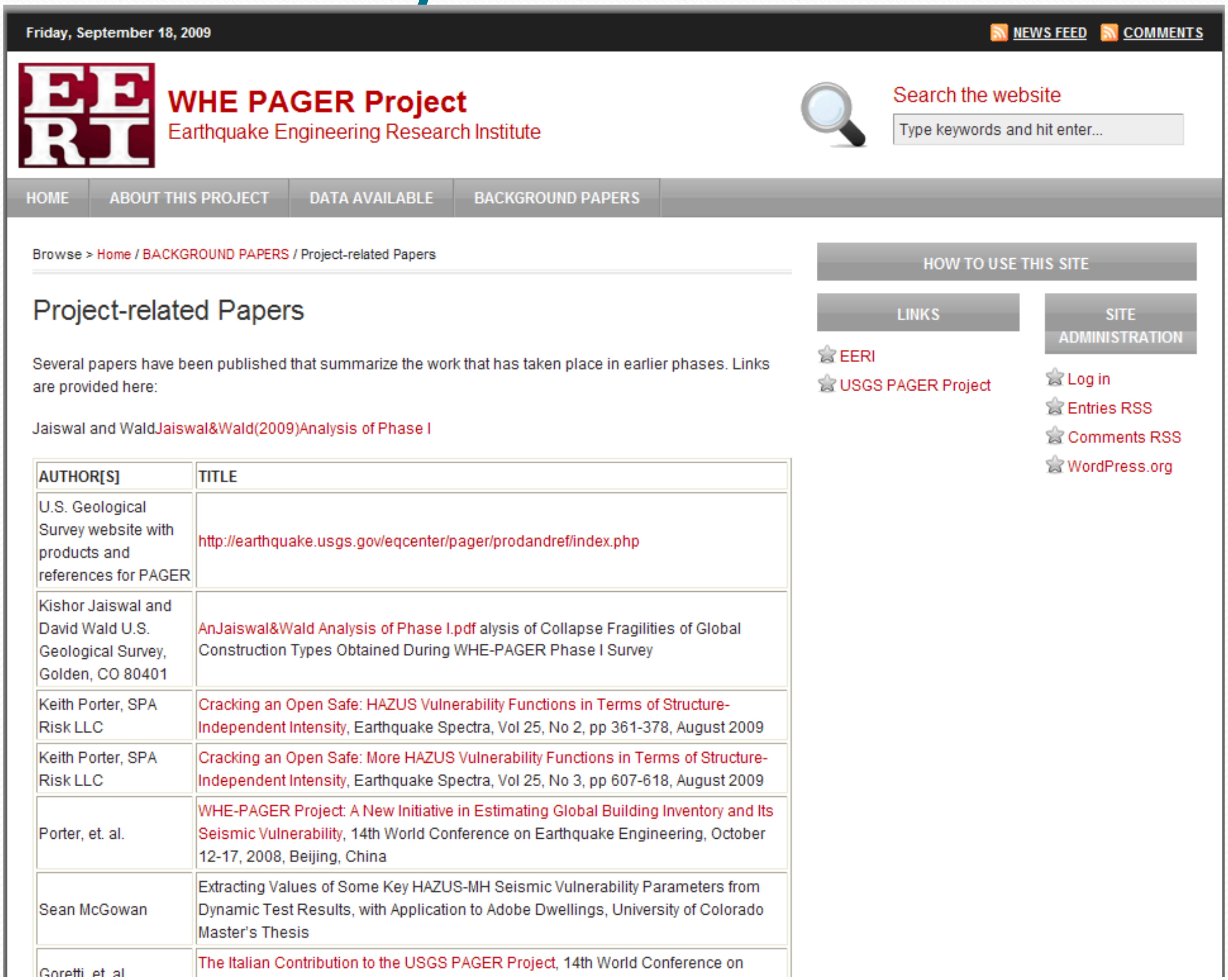
Nonductile Concrete MRF



Alternatively one can use Bayesian Updating -

$$p(\boldsymbol{\beta}|\mathbf{y}) = \kappa L(\boldsymbol{\beta}|\mathbf{y})p(\boldsymbol{\beta})$$

Publications/Website



Friday, September 18, 2009

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Project-related Papers

Several papers have been published that summarize the work that has taken place in earlier phases. Links are provided here:

Jaiswal and WaldJaiswal&Wald(2009)Analysis of Phase I

AUTHOR[S]	TITLE
U.S. Geological Survey website with products and references for PAGER	http://earthquake.usgs.gov/eqcenter/pager/prodandref/index.php
Kishor Jaiswal and David Wald U.S. Geological Survey, Golden, CO 80401	AnJaiswal&Wald Analysis of Phase I.pdf alysis of Collapse Fragilities of Global Construction Types Obtained During WHE-PAGER Phase I Survey
Keith Porter, SPA Risk LLC	Cracking an Open Safe: HAZUS Vulnerability Functions in Terms of Structure-Independent Intensity, Earthquake Spectra, Vol 25, No 2, pp 361-378, August 2009
Keith Porter, SPA Risk LLC	Cracking an Open Safe: More HAZUS Vulnerability Functions in Terms of Structure-Independent Intensity, Earthquake Spectra, Vol 25, No 3, pp 607-618, August 2009
Porter, et. al.	WHE-PAGER Project: A New Initiative in Estimating Global Building Inventory and Its Seismic Vulnerability, 14th World Conference on Earthquake Engineering, October 12-17, 2008, Beijing, China
Sean McGowan	Extracting Values of Some Key HAZUS-MH Seismic Vulnerability Parameters from Dynamic Test Results, with Application to Adobe Dwellings, University of Colorado Master's Thesis
Goretti, et. al.	The Italian Contribution to the USGS PAGER Project, 14th World Conference on

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WHE-PAGER Survey

Phase II

Analytical Parameters (CSM) for non-US constructions

Outcome of Phase II was –

- ❑ Analysis by Keith & Craig (White Paper)
- ❑ Realization of need of additional capacity parameters (Credit: Craig Comartin)
- ❑ SPO2IDA analysis of Phase II data and illustration (Credit: Craig Comartin)

WHE-PAGER Survey

Phase III

Analytical Parameters (CSM & Capacity Boundary)

(through NEHRP project)

Priority Construction Types

Sr. No.	PAGER-STR	Description of Structure
1	W3	Light post and beam wood frame
2	W5	Walls with bamboo/light timber log/reed mesh and post (Wattle and Daub)
3	W6	Unbraced heavy post and beam wood frame with mud or other infill material
4	M	Mud walls
5	A1	Adobe block, mud mortar, wood roof and floors
6	A2	Adobe block, mud mortar, bamboo, straw, and thatch roof
7	A4	Adobe block, mud mortar, reinforced concrete bond beam, cane and mud roof
8	RS3	Local field stones with lime mortar.
9	RS4	Local field stones with cement mortar, vaulted brick roof and floors
10	DS2	Rectangular cut stone masonry block with lime mortar
11	DS4	Rectangular cut stone masonry block with reinforced concrete floors and roof
12	MS	Massive stone masonry in lime or cement mortar
13	UCB	Unreinforced concrete block masonry with lime or cement mortar
14	UFB1	Unreinforced brick masonry in mud mortar without timber posts
15	UFB3	Unreinforced brick masonry in lime mortar
16	UFB5	Unreinforced fired brick masonry, cement mortar, but with reinforced concrete floor and roof slabs
17	RM3	Confined masonry
18	C1	Ductile reinforced concrete moment frame with or without infill
19	C3	Nonductile reinforced concrete frame with masonry infill walls
20	C4	Nonductile reinforced concrete frame without masonry infill walls
21	C6	Concrete moment resisting frame with shear wall – dual system
22	PC3	Precast reinforced concrete moment resisting frame with masonry infill walls
23	S1	Steel moment frame
24	S5	Steel frame with unreinforced masonry infill walls

Analytical Model Parameters

Researchers /Contributors	PAGER-STR	Details
Dina D'Ayala (total 24 types)	UFB DS MS	By Geographic Regions (Erbil, Fener Balat, L'Aquila, Nocera, Serravalle)
Andreas Kappos (total 18 types)	C6	Rise (L,M,H) Code(Low, High) Infill (No, Full, Soft)
D Lang/Y Singh (total 6 types)	UFB	UFB (1,3,5) Rise (1,2)
H Kaushik (total 5 types)	C3	Infill (No, Full, Soft) Rise (All, 4)
A Lang (total 24 types)	CM (with concrete block, with clay bricks)	Peru, Chile, Mexico, Colombia Only capacity parameters Rise (1,2,4)

PAGER-STR

Sr. No.	PAGER-STR	Description of Structure	
1	W3	Light post and beam wood frame	
2	W5	Walls with bamboo/light timber log/reed mesh and post (Wattle and Daub)	
3	W6	Unbraced heavy post and beam wood frame with mud or other infill material	
4	M	Mud walls	
5	A1	Adobe block, mud mortar, wood roof and floors	
6	A2	Adobe block, mud mortar, bamboo, straw, and thatch roof	
7	A4	Adobe block, mud mortar, reinforced concrete bond beam, cane and mud roof	
8	RS3	Local field stones with lime mortar.	
9	RS4	Local field stones with cement mortar, vaulted brick roof and floors	
10	DS2	Rectangular cut stone masonry block with lime mortar	
11	DS4	Rectangular cut stone masonry block with reinforced concrete floors and roof	Dina
12	MS	Massive stone masonry in lime or cement mortar	
13	UCB	Unreinforced concrete block masonry with lime or cement mortar	
14	UFB1	Unreinforced brick masonry in mud mortar without timber posts	
15	UFB3	Unreinforced brick masonry in lime mortar	
16	UFB5	Unreinforced fired brick masonry, cement mortar, but with reinforced concrete floor and roof slabs	Singh/ Lang/ Kaushik
17	RM3	Confined masonry	A. Lang
18	C1	Ductile reinforced concrete moment frame with or without infill	
19	C3	Nonductile reinforced concrete frame with masonry infill walls	
20	C4	Nonductile reinforced concrete frame without masonry infill walls	
21	C6	Concrete moment resisting frame with shear wall – dual system	Kappos
22	PC3	Precast reinforced concrete moment resisting frame with masonry infill walls	
23	S1	Steel moment frame	
24	S5	Steel frame with unreinforced masonry infill walls	

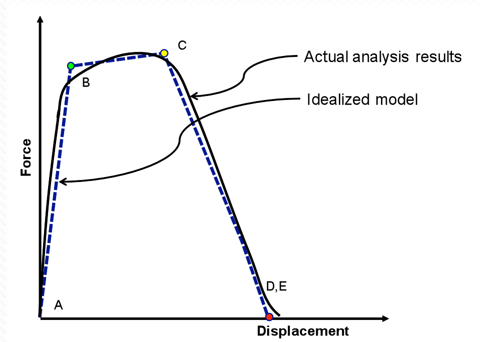
Taiwan (pre-code MBTs)

Capacity parameters:

MBT	Dy (in)	Ay (g)	Du (in)	Au (g)	Belastic	Inventory
C1M	2.044	0.233	33.6	0.63	7%	27 % (all C1)
RMM	2.044	0.21	33.6	0.595	10%	33 % (all RM)

Fragility parameters:

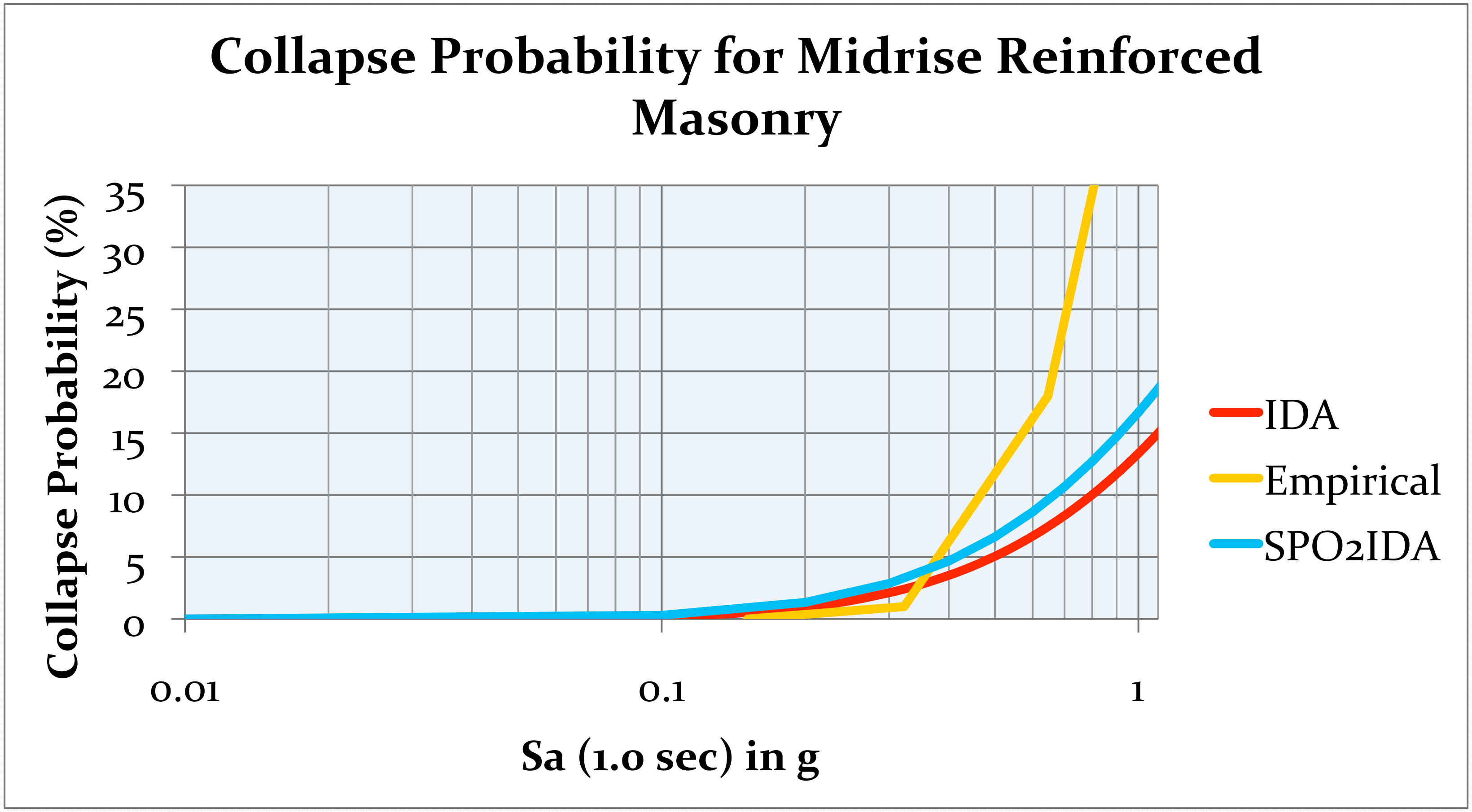
MBT	m2	β2	m3	β3	m4	β4	m5	β5
C1M	14.63	0.82	21.46	0.82	32.67	0.82	48.77	0.82
RMM	14.63	0.82	21.46	0.82	32.67	0.82	48.77	0.82



Capacity Boundary:

							Hardening μ	Hardening slope		Residual plateau	Fracturing μ	Period
MBT	B(Elastic)	m5	Kab	Kbc	Kcd	NEW Kcd	Hard μ	Hard Slope	NEW Soft Slope	Resi. Plateau	Fract μ	Telastic
C1M	7	48.77	0.113992	0.012581	-0.02653	-0.04153	16.43836	0.110366	-0.36432	0	23.86008	0.945645
RMM	10	48.77	0.10274	0.012201	-0.02506	-0.03922	16.43836	0.118752	-0.38176	0	23.86008	0.996085

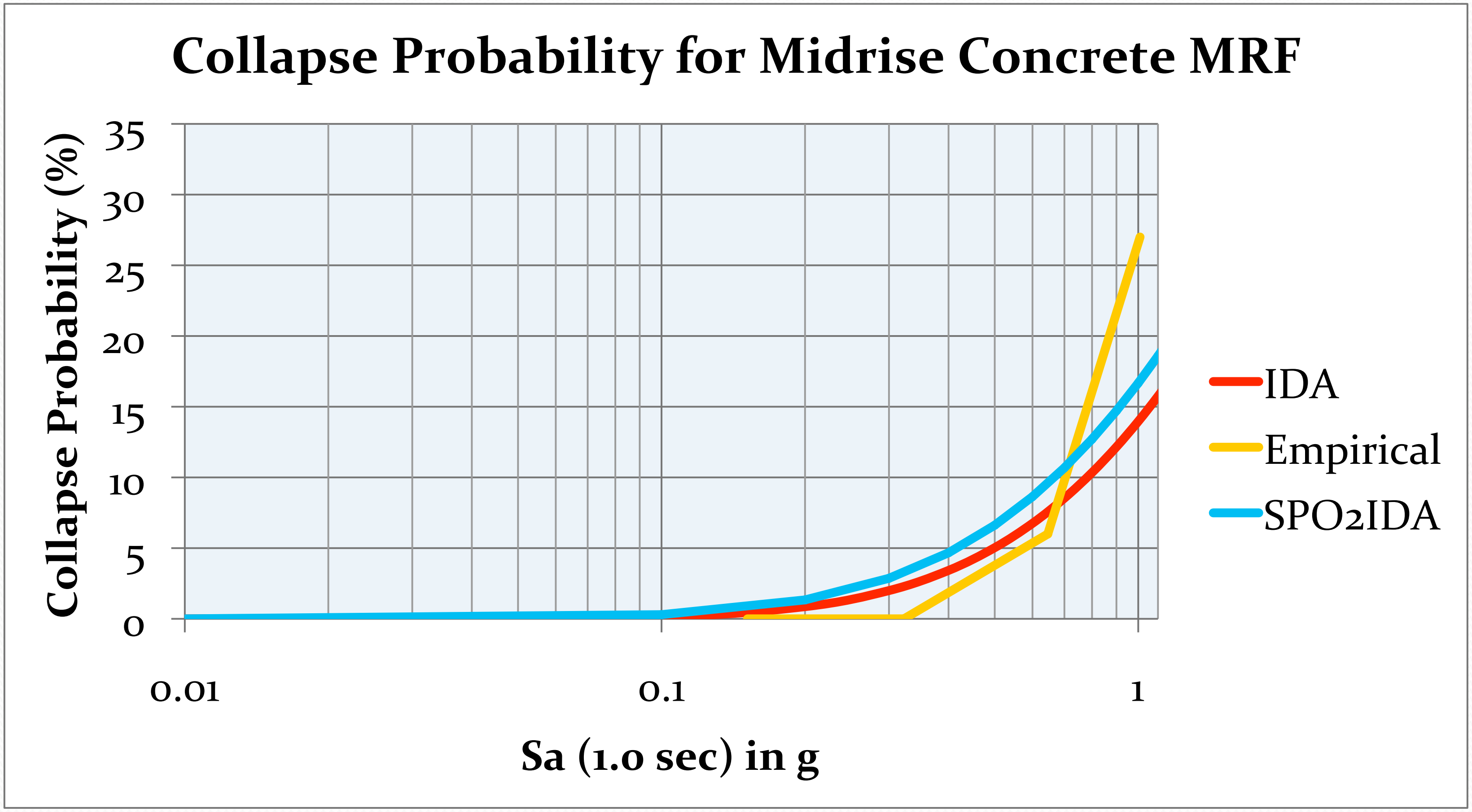
Comparison of different approaches



Credits: a) Jay Lin (WHE-PAGER Survey contribution for Taiwan)

b) Hyeuk Ryu performed IDA analysis

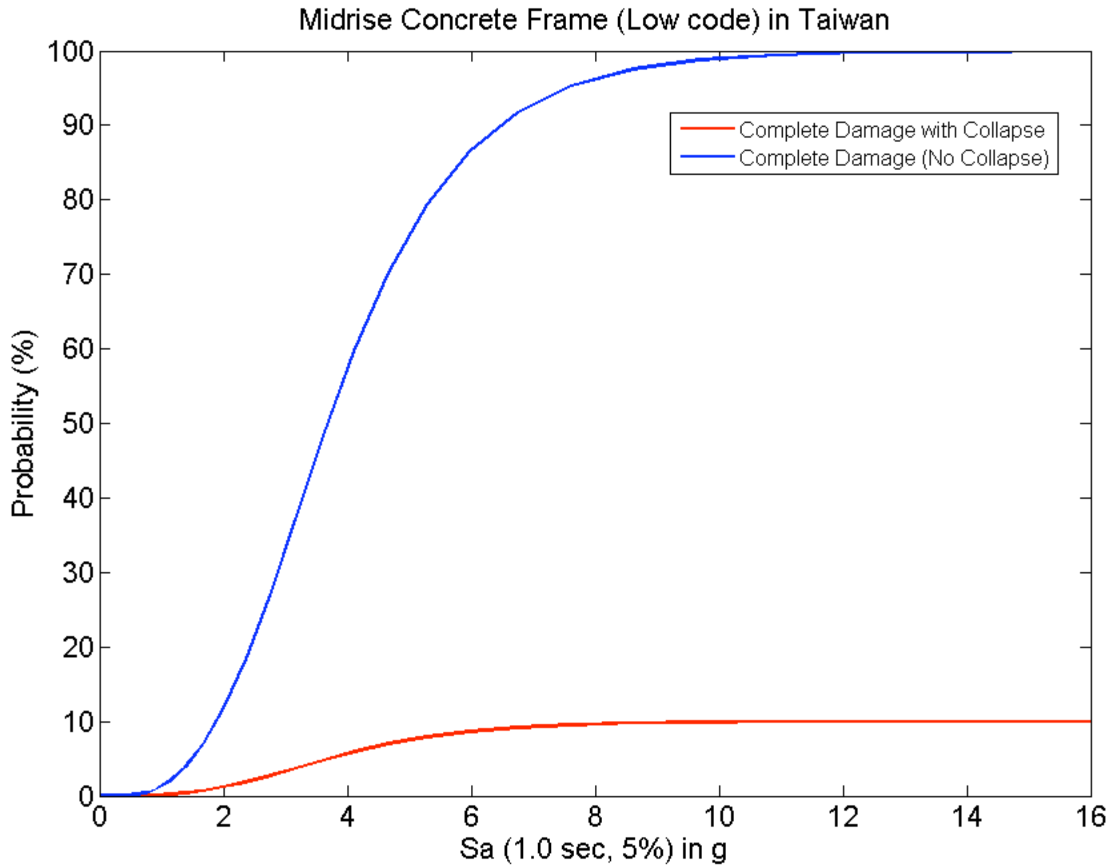
Comparison of different approaches



Preliminary Observation: Analytical approaches overestimate collapses at lower intensity (EDP) and underestimate at high intensity (EDP).

HAZUS Methodology

Input:
Dy = 2.044;
Ay = 0.233;
Du = 33.6;
Au = 0.63;
Be = 0.07;
Kshort = 0.7;
Kmed = 0.59;
Klong = 0.42;
theta5 = 48.77;
beta5 = 0.82;
Pc = 0.1;
M = 7;
R = 20;

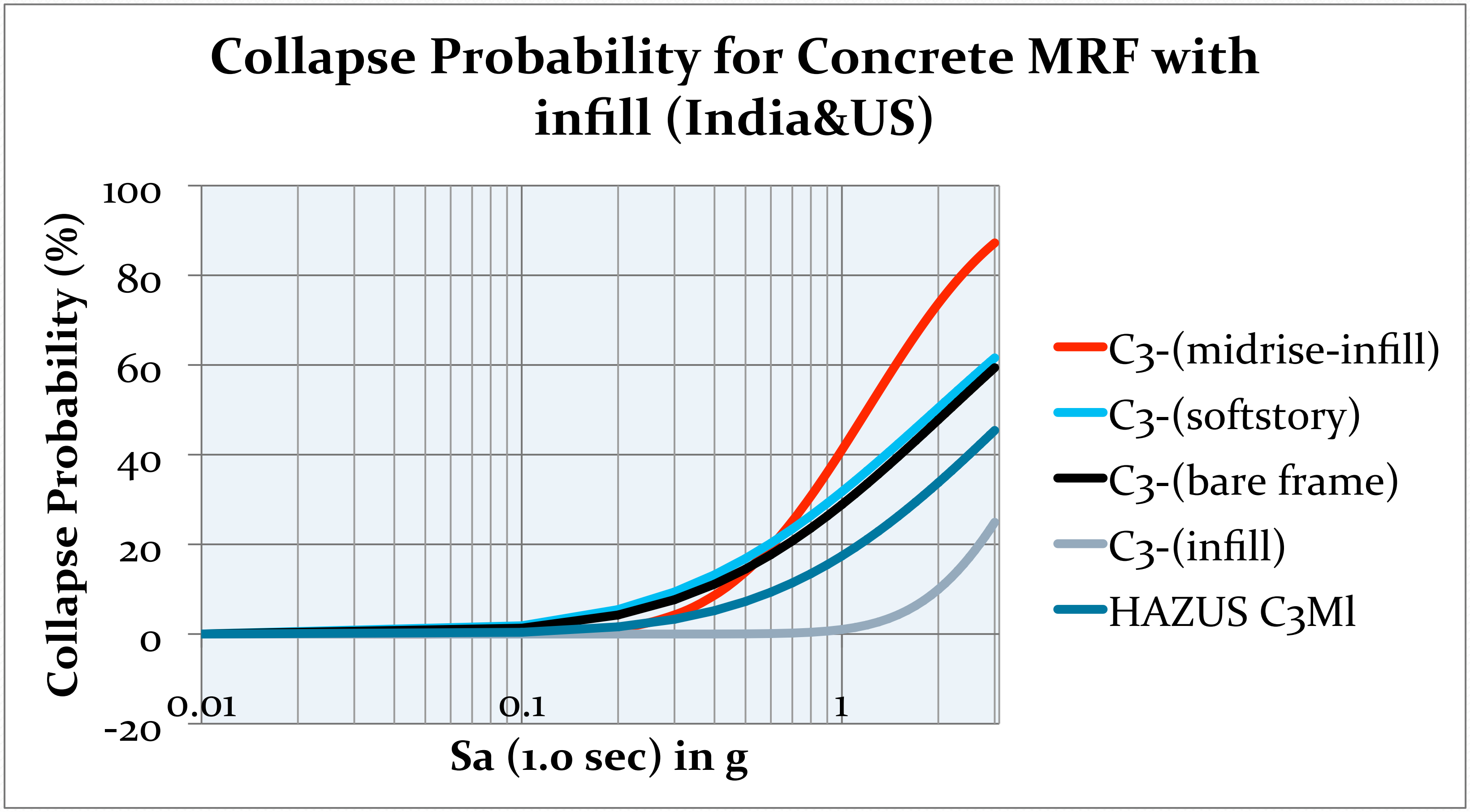


We underestimate the overall collapse probability

- with Pc (Probability of collapse given complete damage state)- 10 %

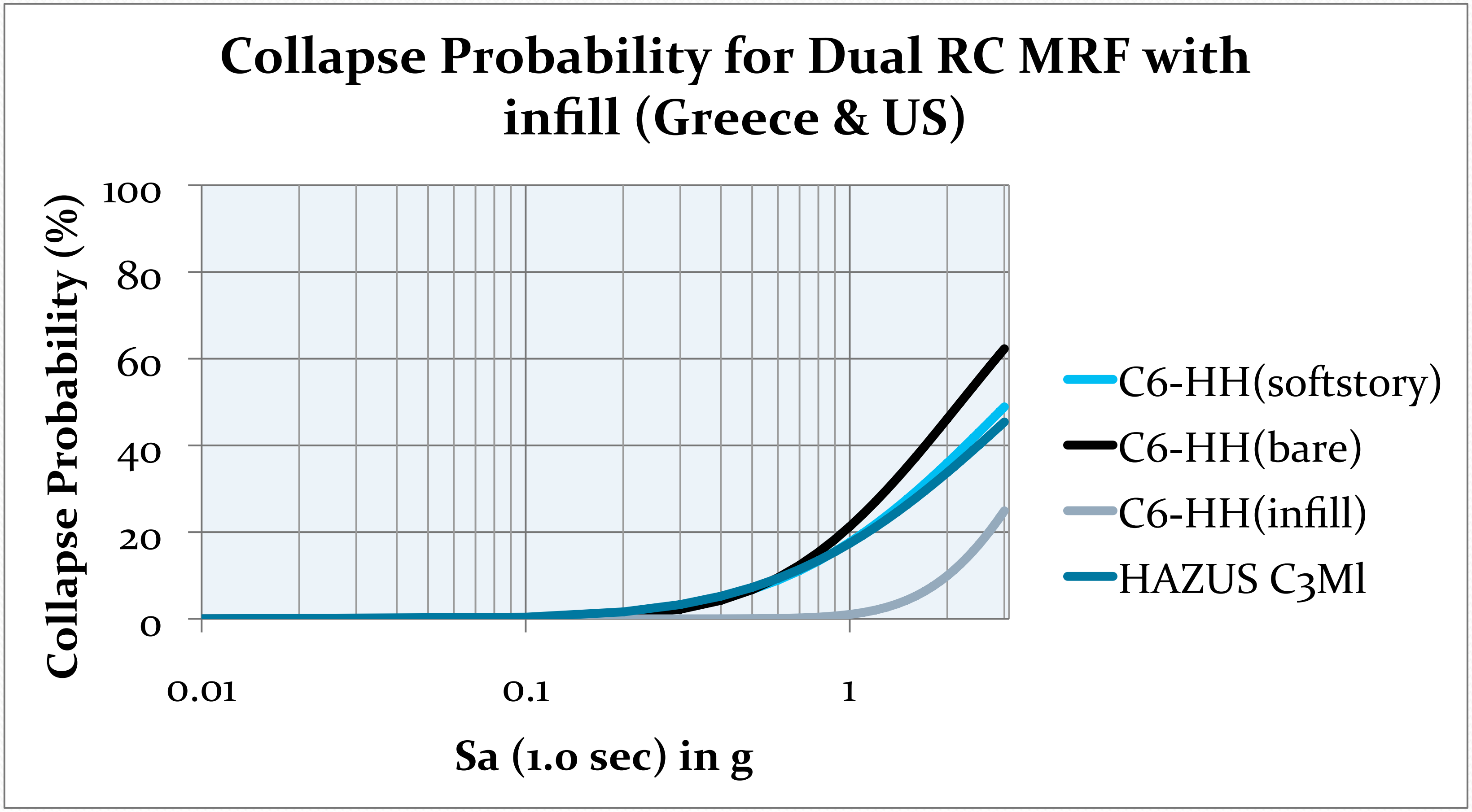
Note: Complete damage state ~ 50 % chance that structure cannot be economically repaired

Comparison of Collapse Fragility



Source: Capacity parameters for Indian types are from Kaushik (2009) WHE PAGER Survey

Comparison of Collapse Fragility



Source: Capacity parameters for Indian types are from Kappos (2009) WHE PAGER Survey

Thank You !!

(For your attention and your valuable contributions)