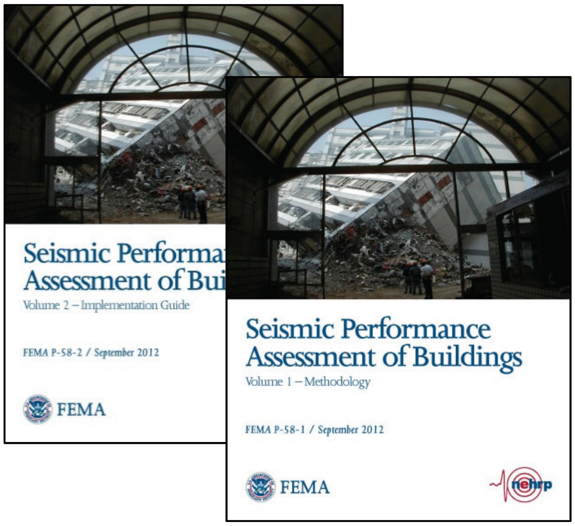

Background Document

FEMA P-58/BD-3.9.29

Fragility of Home Entertainment Equipment

Prepared by

Keith Porter
Dept of Civil, Environmental & Architectural Engineering
University of Colorado
Boulder, Colorado 80309

Submitted to

APPLIED TECHNOLOGY COUNCIL
201 Redwood Shores Parkway, Suite 240
Redwood City, California 94065
www.ATCouncil.org

Prepared for

FEDERAL EMERGENCY MANAGEMENT AGENCY
U.S. Department of Homeland Security
500 C Street, SW
Washington, D.C. 20472

August 21, 2008

Background Documentation

FEMA P-58 Background Documents are a series of reports documenting the technical background and source information for key aspects of the FEMA P-58 methodology and its implementation. These reports were developed over the course of the 10-year ATC-58/ATC-58-1 Projects funded under FEMA Contracts EMW-2001-RP-0056 and HSFEHQ-06-D-1105.

Background Documents were developed by consultants, serving at various levels within the project hierarchy, reporting the results of: (1) decisions on technical development protocols; (2) focused studies on the development of key aspects of the methodology; (3) documentation of recommended procedures; and (4) collection of available data for the development of structural and nonstructural fragilities. They were initially intended to serve as a record of the technical state-of-knowledge at the time they were produced, and as resources for the development of the eventual project reports. As such, they represent a snapshot in time, and may, or may not, match the technical content, recommended procedures, or data incorporated into the final methodology and its implementation.

This Background Document is intended for the purpose of providing supplemental knowledge to users of the FEMA P-58 methodology. Information contained herein has not been independently verified for accuracy as a stand-alone document, and may have been superseded in its final implementation within the methodology. Specifically in the case of certain nonstructural component fragilities, the NISTIR fragility classification numbering scheme was modified over the course of the project, and the fragility classification number assigned in this document might be different from numbers assigned in the final fragility database. Users of information in this document assume all liability arising from such use.

Notice

Cover illustration – Primary resource documents for the FEMA P-58 *Seismic Performance Assessment of Buildings, Methodology and Implementation* series of products: FEMA P-58-1, *Volume 1 – Methodology*, and FEMA P-58-2, *Volume 2 – Implementation Guide*.

Fragility of home entertainment equipment

Keith Porter (08/21/2008)

Table 1. Summary of results

Fragility, damage measures, and consequences for			
Component category:	E2022.020, Home entertainment equipment, unknown inst E2022.021, Ditto, high frict coeff, support secured to wall E2022.022, Ditto, high frict coeff, support not secured E2022.023, Ditto, low frict coeff, support not secured		
Basic composition:			
Units:	ea piece of equipment		
Demand parameter:	Peak diaphragm acceleration		
Number of damage states:	1		
If multiple damage states:	□ ordered; □ mutually exclusive; □ simultaneous		
Author and date:	Keith Porter 21 Aug 2008		
Damage states, fragilities, and consequences			
	DS1	**DS2**	**DS3**
Description:	Falls, does not function		
Illustration:	 Figure 1. Speaker falling from a shelf in 2nd story of house shaken to 0.89g		
Median demand (θ)(1):	0.8g		
Dispersion (β)(1):	0.5		
Probability(1):			
Correlation:	0		
Repairs required:	Replace		
Possible consequences:			
Repair cost (Y/N/?):	Y		
Death or injury (Y/N/?):	Y		
Inoperative facility (Y/N/?):	N		
Red tagging (Y/N/?)	N		
Comments:			

(1) If ordered damage states, leave "probability" blank. If mutually exclusive or simultaneous damage states, provide parameters in DS1 column only, and probabilities of each damage state in "probability."

Table 2. Summary of supporting information

Literature summary

Saeki et al. (2000). This study appears to be the only thorough examination of the fragility of home entertainment equipment, which included audiovisual equipment, personal computers, telecommunications equipment, and musical instruments. These authors report on a questionnaire-based survey of damage to household property experienced in the 1995 Kobe earthquake. A total of 1,450 questionnaires were sent out over a wide area centering on Hyogo and Osaka Prefectures, with 965 responses. The questions covered building damage and damage to household property. The questionnaire requested information about the address, structure type, degree of building damage, and household property. Fragility functions in the form of Gaussian cumulative distribution functions were created for six types of durable household property, of which one (category D) was household entertainment equipment. The damage state being falling to the floor or toppling over, and the EDP was JMA intensity. The authors estimated JMA intensity using the following approximation based on instrumentally measured peak ground velocity, V_{max}, in cm/sec:

$$x = 2.30 + 2.01\log_{10}\left(V_{\max}\right) \quad (1)$$

where x denotes JMA intensity. The authors produce the fragility function

$$P\left[DS = 1 \middle| I_{JMA} = x\right] = \Phi\left(\frac{x - 6.95}{1.16}\right) \quad (2)$$

Filiatrault et al. (2001). These authors report on a full-scale shake-table test of a furnished woodframe house subjected to uniaxial shaking with PGA = 0.89g (Rinaldi fault-normal record; see Figure 2). Figure 1a shows the first of two stereo speakers falling from a shelf in a 2nd-story bedroom, approximately 2.6 seconds after the initiation of strong motion (in the direction of view, at approximately 0.6 to 0.9g of base acceleration, perhaps 0.9 to 1.4g at the second floor); the second was secured to the shelf, although the shelf fell approximately 4.3 seconds after the initiation of strong motion (at approximately 0.5g of base acceleration, perhaps 0.8g at the second floor). Figure 1b shows a television falling from a 1st-story shelf or cabinet approximately 3.2 seconds after the initiation of shaking (motion in the plane of the page, at approximately 0.5g).

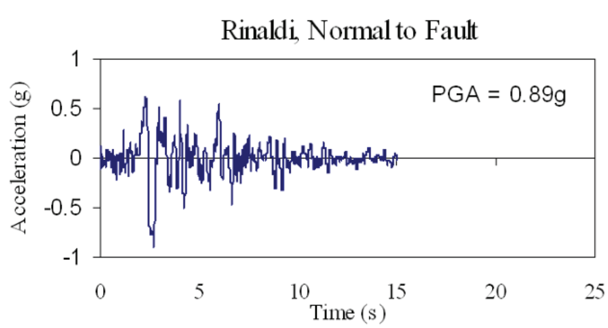

Figure 2. Record used in Filiatrault et al. (2001) full-scale shake-table test of furnished house

Figure 3(a). Speaker falling from a shelf in 2nd story of house shaken to 0.89g; (b) television falling in 1st story (Filiatrault et al. 2001)

ANALYSIS

It is worthwhile to convert the Saeki et al. (2000) fragility functions from a JMA-intensity basis to a PDA basis for present purposes. Note that the median value in Equation (2) is 7, approximately the maximum JMA intensity observed in the 1995 Kobe earthquake (on which the fragility functions was based). The same locations experienced PGA ≈ 1.1g (Yamaguchi and Yamazaki 2001). Using the approximation that PDA ≈ 1.5PGA suggests that the median PDA causing household entertainment equipment to fall to the floor or topple over is approximately 1.6g. If it is further assumed that the logarithmic standard deviation of a fragility function in terms of PGV is approximately equal to that of the fragility function in terms of PDA, one can substitute Equation (1) into (2) to produce a lognormal fragility function with EDP = V_{max}, median value x_m = 206 cm/sec, and logarithmic standard deviation β = 1.3:

$$\begin{aligned} P\left[DS=1 \middle| V_{\max}=x\right] &= \Phi\left(\frac{2.30+2.01\log_{10}(x)-6.95}{1.16}\right) \\ &= \Phi\left(\frac{\ln(x/206)}{1.3}\right) \end{aligned} \qquad (3)$$

again with V_{max} indicating peak ground velocity measured in cm/sec. A logarithmic standard deviation β = 1.3 is fairly large (0.2 to 0.6 being more common), suggesting that one or more of the following may be the case:

- V_{max} is a poor predictor of damage to stereo equipment
- Equipment reflected in Saeki's category D are diverse in terms of fragility
- Multiple failure modes were involved in producing the damage, e.g., overturning of the furniture housing the home entertainment equipment, *or* the equipment sliding off of shelves.

Note the fairly simple translation from σ = 1.16 to β = 1.3 as follows: the coefficient of 2.01 applied to $\log_{10}(I_{JMA})$ is divided by ln(10) when changing from base-10 logarithm to base-*e*, and becomes a coefficient of 0.87. Dividing numerator and denominator by 0.87 eliminates the coefficient in the numerator and multiplies the denominator by 1.15. Thus, σ = 1 (EDP in terms of JMA intensity) equates with β = 1.15 (EDP in terms of PGV).

This is a high value for β, far outside the typical bounds of 0.3 to 0.6, indicating that the EDP is a

poor predictor of damage, or that the equipment are very diverse. In any event, one can replace the high β with 0.6 while retaining the EDP associated with 10% failure probability, adopting a revised $\beta' = 0.6$, defining $x_{0.1}$ as the EDP associated with 10% failure probability, and calculating a revised median, denoted by x'_m, as follows: $$\Phi\left(\frac{\ln(x_{0.1}/x_m)}{\beta}\right)=0.1 \qquad x_{0.1}=x_m\exp(-1.28\beta) \qquad \Phi\left(\frac{\ln(x_{0.1}/x'_m)}{\beta'}\right)=0.1 \qquad x'_m = x_{0.1}/\exp(-1.28\beta') = x_m\exp(-1.28\beta)/\exp(-1.28\beta') = x_m\exp(1.28(\beta'-\beta)) \qquad (4)$$ with $\beta = 1.15$, $\beta' = 0.6$, and $x_m = 1.6$, Equation (4) produces $x'_m \approx 0.80$g. The three data points from the Filiatrault et al. (2001) tests constitute method-A data (actual EDP at which failure occurred), with failure accelerations of 0.5, 0.8, and 1.2g, i.e., whose median value (assuming lognormal distribution) is $x_m = 0.8$g, and whose logarithmic standard deviation is 0.4. Since there are only 3 specimens, an additional β of 0.25 is SRSS'd with the β from the best fit, resulting in a final $\beta = 0.5$.

Number of specimens tested:	3
Construction quality:	□ exceeds □ meets □ does not meet requirements of: N/A
Seismic installation conditions:	Not secured; resting on shelves
Loading protocols applied:	Rinaldi fault-normal record; see Figure 2.
Method for observing demand:	2nd-floor acceleration estimated as 1.5 x base acceleration at time of failure
Method for observing damage:	Video with timestamp

Table 3. Table of test results

Specimen	**DS1**		**DS2**		**DS3**		**Comment**
	Data type: A		**Data type:**		**Data type:**		
	demand	***f***	***demand***	***f***	***demand***	***f***	
1	0.5g	1					
2	0.8g	1					
3	1.2g	1					

Table 4. Quality tests

Quality test	DS1	DS2	DS3
Passes Lilliefors goodness of fit test? (Type A only)	Y	NA	NA
Are θ and β within 20% of past results? If not discuss.	NA		
Are $0.2 \le \beta \le 0.6$? If not discuss.	Y		
Discussion. Lilliefors (1968) table only goes down to N = 4, but this sample passes at 5% significance level for N = 4, which is a narrower constraint than N = 3.			

Table 5. Extrapolation to other detailed conditions and to average conditions

Condition (describe)	From tests?	DS1		DS2		DS3	
		θ	β	θ	β	θ	β
Best: object is fastened to a wall or resting on rubber feet or a rubber pad on a shelf or other surface that is itself secured to the building frame	N	2.5	0.5				
Moderate: object is resting on tall unsecured surface or with high coefficient of static friction between the object and the surface, e.g., rubber feet or rubber pad	N	1.0	0.5				
Worst: object is resting on tall unsecured surface or with low coefficient of static friction between the object and the surface, e.g., smooth wood, metal, or plastic surfaces at the interface	N	0.4	0.5				
Average: generally unsecured and with mixed base conditions	Y	0.8	0.5				
Basis for extrapolation. What factors affect θ and β? Median capacity is probably affected by (a) whether the component is secured to the wall, as in wall-mounted video displays, with such components probably being rugged; (b) for objects that simply rest on a flat surface, the coefficient of static friction between the equipment and its supporting surface, with rubber feet or a rubber pad probably producing higher median capacity than plastic or metal; (c) whether the components rests on a tall unsecured piece of furniture such as a tall standing bookshelf; and (d) the height and aspect ratio of the object, with smaller or more slender objects having lower capacity. Fragility for average is taken as the tested condition here, and fragility for worst is simply guessed as ½ x average. Median for moderate is taken as 25% higher than that of average, by judgment.							

"From tests" means that the tests reported here are believed to represent this condition level

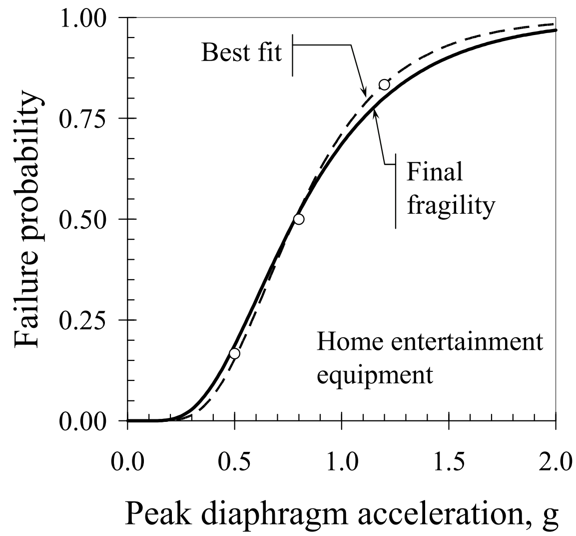

Figure 4. Fragility functions and data for home entertainment equipment

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Revision history

1.0	21 Aug 2008	Initial release in frag spec format; based on 18 Dec 2006 report in fragility compendium