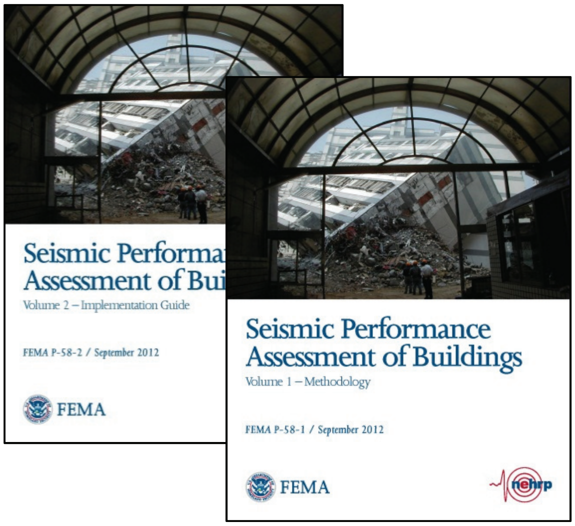

Background Document

FEMA P-58/BD-3.9.13

Fragility of Hydraulic Elevators for ATC-58

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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contained herein has not been independently verified for accuracy as a stand-alone document, and may have been superseded in its final implementation within the methodology.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 hydraulic elevators for ATC-58

Keith Porter (08/21/2008)

Table 1. Summary of results

Fragility, damage measures, and consequences for			
Component category:	D1014.020, Hydraulic elevators, unknown installation D1014.021, Hydraulic elevators installed 1973-1994 D1014.022, Hydraulic elevators installed pre-1973		
Basic composition:	Hydraulic elevator		
Units:	Ea		
Demand parameter:	PGA		
Number of damage states:	9		
If multiple damage states:	□ ordered; □ mutually exclusive; ☒ simultaneous		
Author and date:	Keith Porter 12 Dec 2007		
Damage states, fragilities, and consequences Failure includes any of the following: damaged controls (30% of failed elevators), damaged vane and hoistway switches (20%), damaged entrance and car door (30%), oil leak in hydraulic line (10%), bent cab stabilizers (20%), snagged ropes or traveling cables (10%), hydraulic tank failure (30%), flooring damage (20%), damaged car guide shoes (20%).			
	DS1	**DS2**	**DS3**
Description:	Any of the above		
Illustration:			
Median demand (θ)$^{(1)}$:	0.41g		
Data dispersion (β_d)$^{(2)}$	0.28		
Uncertainty (β_u)$^{(2)}$	0.10		
Total dispersion (β)$^{(1)}$	0.30		
Probability$^{(1)}$:			
Correlation:	0		
Repairs required:			
Possible consequences:			
Repair cost (Y/N/?):	Y		
Death or injury (Y/N/?):	Y		
Inoperative facility (Y/N/?):	Y		
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."

(2) For methods A and B only, provide β_d and β_u and explain in the "comments" row any β_u value that differs from recommendations in Appendix C.

Table 2. Summary of supporting information

Literature summary: See Porter 2007. Draws upon observations of 14 hydraulic elevators shaken by the 1994 Northridge earthquake and discussed by Finley et al. (1996), as well as 77 hydraulic elevators at Stanford University shaken by the 1989 Loma Prieta earthquake, reported by Schiff (writing in EERI 1990).	
Number of specimens tested:	91
Construction quality:	☐ exceeds ☐ meets ☐ does not meet requirements of: 1973 UBC
Seismic installation conditions:	Varies
Loading protocols applied:	Loma Prieta and Northridge earthquakes
Method for observing demand:	Interpolate PGA from 2 nearest strong motion instruments
Method for observing damage:	Finley et al. examined elevators and interviewed facility engineers

Table 3. Table of test results (data type = B)

Location	***Demand* (*PGA*, g)**	**No. exposed**	**No. damaged**	**Earthquake**
Stanford University	0.26	77	4	Loma Prieta
Valley Presbyterian	0.38	4	2	Northridge
St Johns Hospital Main Wing	0.50	1	1	Northridge
St Johns Hospital South Wing	0.50	1	0	Northridge
St Johns Hospital Mental Health Center	0.50	2	2	Northridge
Cedars Sinai Becker	0.26	1	0	Northridge
Cedars Sinai Cancer	0.26	2	0	Northridge
Northridge Medical Center	0.45	2	1	Northridge
USC Medical Center	0.25	1	0	Northridge
Total		91	10	

Table 4. Quality tests

Quality test	**DS1**	**DS2**	**DS3**
Passes Lilliefors goodness of fit test? (Type A only)	NA		
Are θ and β within 20% of past results? If not discuss.	NA		
Are $0.2 \leq \beta \leq 0.6$? If not discuss.	Y		
Discussion			

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: installed in 1973 or later	N	0.50g	0.3				
Moderate	Y/N						
Worst: pre-1973 installation	N	0.30	0.3				
Average: unknown or mix of pre-, post-1973	Y	0.41	0.3				
Basis for extrapolation. What factors affect θ and β? Finley et al. make several recommendations for strengthening hydraulic elevators that can be interpreted for relevance							

here. They advocate adding or strengthening guide rail support brackets (but provide no specific guidance re spacing or anchorage); ensuring that thickness of guide rail retainer plates is 3/8 in or thicker; and ensuring that anchorage of pump units and piping complies with Title 24. Each of these should increase θ. Extrapolated to best and worst by adding and subtracting 25% of average capacity, based on more-detailed analysis of traction elevators.

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

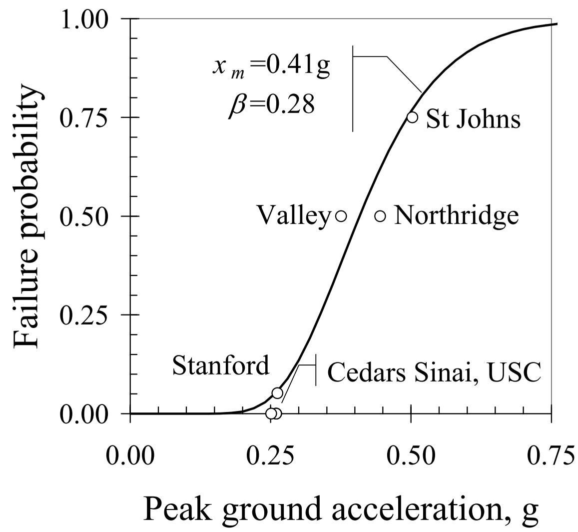

Figure 1. Fragility function fit to hydraulic elevator damage at Stanford University in the 1989 Loma Prieta Earthquake and at five hospitals in the 1994 Northridge Earthquake.

REFERENCES CITED

(EERI) Earthquake Engineering Research Institute, 1990. Loma Prieta Earthquake reconnaissance report. *Earthquake Spectra*, 6 (S1).

Finley, J., Anderson, D. and Kwon, L., 1996. *Report on the Northridge Earthquake Impacts to Hospital Elevators*. Contract No. 94-5122. California Office of Statewide Health Planning and Development (OSHPD), Sacramento, CA

Porter, K.A., 2007. Fragility of hydraulic elevators for use in performance-based earthquake engineering. *Earthquake Spectra.* 23 (2), May 2007, 459-469

Revision history

1.0	21 Aug 2008	Initial release