ATC-50 SEISMIC GRADING SYSTEM FOR THE DETACHED WOOD-FRAME, SINGLE-FAMILY RESIDENCE

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ABSTRACT

The typical wood-framed house has enjoyed a good history of seismic performance meeting the objectives of the minimum life safety. It belongs to the low-rise category of buildings and is light and flexible with redundancy. In the past structural engineers have given very little attention to the seismic performance of this type of building simply due to its high probability of satisfying the minimum life safety standards.

However, earthquakes like the 1994 Northridge, which occurred in an area that is densely populated with single-family wood-frame dwellings have raised new concerns among the Structural Engineers, Building Officials, Banks and Insurance Agencies. They have discovered that these houses are not designed with adequate lateral load capacity or stiffness and are built with much less care. In addition, it has also become obvious that while a dwelling may meet all the code life-safety requirements, the damages could be large enough to cause the dwelling to be non-habitable. Such conditions are a huge financial loss to the homeowner, the bank, the insurance carrier and the government.

Learning from past lessons, there is a need for a rapid seismic evaluation of the single-family dwellings. A system which will allow a trained inspector or an engineer to inspect a dwelling, and as a part of the inspection, complete a multiple choice questionnaire which will then lead to a score/grade. The grade will allow the concerned agencies to understand the seismic vulnerability and the potential of damage to such dwelling without having to perform a detailed structural analysis. This paper will introduce the ATC-50 Seismic Grading Form developed by the authors specifically for the single-family dwellings located in the City of Los Angeles (COLA).

PROJECT TEAM

The project team consists of David C. Breiholz, Shafat A. Qazi, John H. Wiggins, Craig Taylor and Nels Roselund. In addition, Ronald Eguchi is acting as the Project Director on

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behalf of ATC. A Project Engineering Panel (PEP) consisting of several well-known Structural Engineers and Building officials are overseeing the entire project.

BACKGROUND

After the SEAOSC/COLA Northridge Earthquake task force published its findings, some people in the city of Los Angeles saw an opportunity to contribute to reducing this loss in future earthquakes.

Three key individuals who pursued this idea, Perry Singerman, Scott McGill and Karl Deppe, requested a grant from the California Governor's Office of Emergency Services and FEMA. They presented a comprehensive project work plan describing in detail the steps for developing a seismic grading and retrofitting scheme for detached, single-family, wood-frame dwellings. The grant was approved by FEMA. The project plan that is now being managed by the Applied Technology Council (ATC) for COLA is required to develop a seismic rating system and will then be tested on five hundred dwellings. As a part of the project plan, a detailed retrofit guideline will be developed that is coordinated with the seismic vulnerability issues revealed by the rating inspection. Utilizing the guidelines with incentives will provide seismic hazard reduction along with a revised grade for the dwelling.

Testing of the proposed methodologies will occur in a pilot program near the end of the project. Preliminary versions of the proposed methodologies will be used to evaluate and grade approximately 500 detached, single-family, wood-frame dwellings in the Los Angeles area, rehabilitate (retrofit) approximately 50 of these buildings found to have inadequate earthquake resistance, and re-evaluate/re-grade the retrofitted buildings. Following completion of the pilot implementation program and based on its results, the preliminary form will be revised as appropriate.

Earthquake Loss Data

The initial effort of the project team was a search of references for earthquake loss data on wood-frame, single-family residences. The following are some key references that were found to be valuable and appropriate to the form in addition to those listed at the end of this paper:

- A summary of the structural performance of single-family, wood-frame housing, U.S. Department of Commerce, NIST
- Northridge Earthquake Research: City data and summaries of reports related to USC field investigations. Prepared for CUREE by USC, funded by FEMA.
- FEMA 273 & 274 Wood
- The Homeowner's Guide to Earthquake Safety, California Seismic Safety Commission, January 1994
- ATC-21 Rapid Visual Screening of Buildings for Potential Seismic Hazards
- EERI CD-ROM Collection – The Northridge Earthquake January 17, 1994 Collection Post Earthquake Reconnaissance Report

Craig Taylor, PHD, led this existing data research effort and provided summaries for all of the findings with the focus on the 1971 San Fernando earthquake and the 1994 Northridge earthquake. John Wiggins, P.E., PHD, analyzed the insurance loss data specific to COLA. The research findings, loss data and dwelling inspection experience led to the six main damageability categories. The categories were then defined and weighted, redefined and re-weighted with the final ballot for weighting coming after chosen questions were assigned to each category.

Rating Overview

Since ATC-50 is unprecedented as far as any public, non-proprietary grading or ranking of a dwelling being available to insurers or lenders, the expectation of this first grading form is only to be a ranking with respect to average performance. Thus, the user should not expect a Probable Maximum Loss (PML) from a quick site inspection. If one insists on the PML, it is the logical product of evaluation, which follows grading and precedes mitigation. With "average" as the benchmark, the team chose four letter grades "A" through "D", with "B" and "C" being average.

Form Criteria

- Length - 2 sides of 2 pages maximum for inexpensive utilization.
- Layout - Dual columns grouped by the categories.
- Self-contained - No attachments of instructions, explanation or commentary.
- Pre-weighted answers may be "T-F", "Yes", "No", "H"-"M"-"L", or multiple choice.
- Easily updated – periodically or for other jurisdictions.
- Easily "upgraded" – verification of mitigation simply eliminates penalty points.

Criteria for Questions

- Must satisfy at least one of the "Ten Commandments" of potential damage to qualify.
    1. Horizontal discontinuity / irregularity (split levels)
    2. Vertical discontinuity / irregularity (non-stacking exterior walls)
    3. In-plane discontinuity (glass wall / no drags)
    4. Non-parallel resisting systems (torsion)
    5. Foundation weakness (discontinuous/URM/no bolts)
    6. Soft-story / weak-story (upper stories over garage/Glass wall)
    7. Site instability (cut-fill pad/neighboring slopes)
    8. Materials deficiency (condition/age/mix)
    9. Mass irregularity (heavy roof)
    10. Non-structural (chimney/water heater/veneer)

- Grader is assumed to be a trained inspector.
- No unanswered questions – Question must be simple enough to answer by observation alone or a simple table on the form.
- Use UBC or other standards wherever appropriate.

- No redundancy or mix of categories.

Dwelling Damageability Range (DDR)

- Since some "good" structures can exhibit poor seismic performance and vice versa, the grade must represent a range of potential damage.
- To improve a DDR or raise a grade as incentives are presented, it must be very clear in the form and simple for the grader (inspector) how points are restored when mitigation occurs.

Coordination with Seismic Retrofit Guidelines Team

Looking at the total scope of the ATC-50 project, it is understandable that the City and ATC would lead off with seismic vulnerability of the dwelling and its grading, and it is logical that the retrofit guidelines follow the grading system. The need to interconnect the two is clear. The penalty type weighting is provided for categories and each specific question. The coordination with Robert Bruce's (Wiss Janney Elstner & Associates) retrofit guidelines group will be meaningful when a weighted vulnerability is tied to a mitigation approach. The key to the guidelines is the vulnerability weighting of the grading.

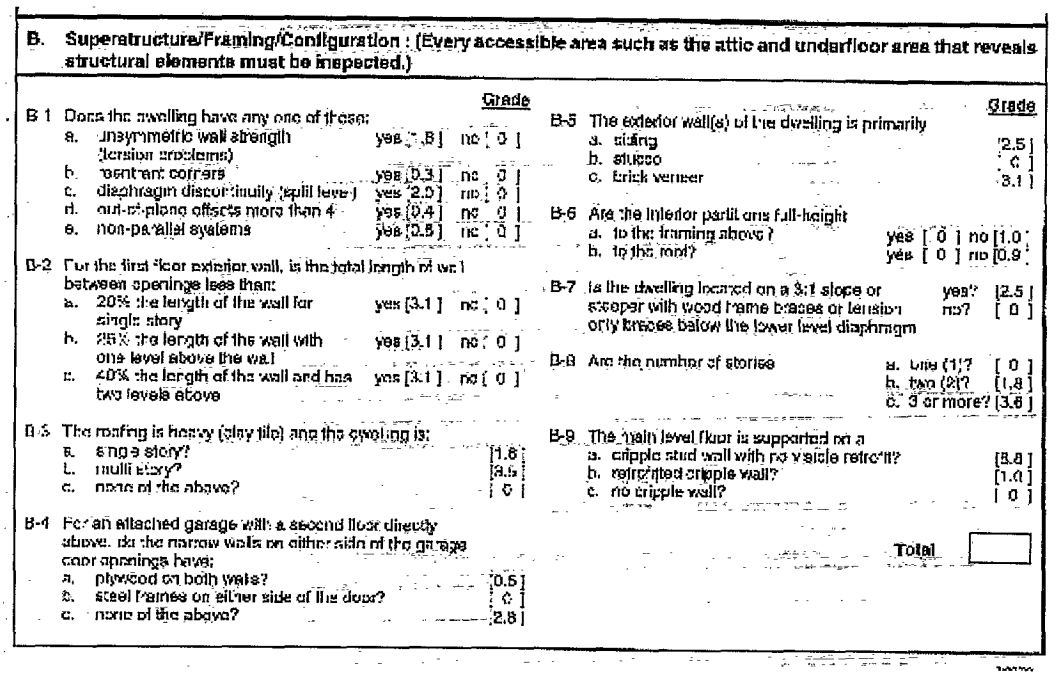
Damageability Category Definitions / Relative Weighting:

The table shown below defines the six main categories of the form and the associated maximum negative points that a building can get. The sixth category, Regional Conditions, is used at the end to amplify the penalties depending on where the building is located.

	Damageability Category	Project Team's Definition	% Contribution
1.	FOUNDATION	The structure between the ground and wood framing that includes continuous footings, isolated piers and pads and connectors.	19
2.	FRAMING CONFIGURATION OF SUPERSTRUCTURE (includes under-floor structure)	The structure and the shape of the structure above the foundation. The shape being formed by the site topography and framing members.	34
3.	NON-STRUCTURAL MISCELLANEOUS	All elements that make up dwelling that are not part of the structure but may contribute to potential damage and loss. Miscellaneous groups are contributors to potential loss and not included in another category.	10
4.	LOCAL SITE CONDITIONS	Topography, soil conditions, neighboring properties.	14
5.	CONDITION OF STRUCTURAL ELEMENTS	The "state of fitness" of all structural elements and their connections including foundation, metal connectors, and secondary structural members.	23
6.	REGIONAL CONDITIONS	Seismicity, geology Tsunami zone, liquefaction	

Sample of the Format:

Shown below using section "B" as an example is the simple format that presents the pre-determined penalty points to the trained inspector to be circled and totaled.



B. Superstructure/Framing/Configuration : (Every accessible area such as the attic and underfloor area that reveals structural elements must be inspected.)

		Grade
B-1	Does the dwelling have any one of these:	
	a. unsymmetric wall strength (torsion problems)	yes [.8] no [0]
	b. reentrant corners	yes [0.3] no [0]
	c. diaphragm discontinuity (split level)	yes [2.0] no [0]
	d. out-of-plane offsets more than 4'	yes [0.4] no [0]
	e. non-parallel systems	yes [2.5] no [0]
B-2	For the first floor exterior wall, is the total length of wall between openings less than:	
	a. 20% the length of the wall for single story	yes [3.1] no [0]
	b. 25% the length of the wall with one level above the wall	yes [3.1] no [0]
	c. 40% the length of the wall and has two levels above	yes [3.1] no [0]
B-5	The roofing is heavy (clay tile) and the dwelling is:	
	a. single story?	[1.6]
	b. multi story?	[3.5]
	c. none of the above?	[0]
B-4	For an attached garage with a second floor directly above, do the narrow walls on either side of the garage door openings have:	
	a. plywood on both walls?	[0.5]
	b. steel frames on either side of the door?	[0]
	c. none of the above?	[2.8]

		Grade
B-5	The exterior wall(s) of the dwelling is primarily	
	a. siding	[2.5]
	b. stucco	[0]
	c. brick veneer	[3.1]
B-6	Are the interior partitions full-height	
	a. to the framing above?	yes [0] no [1.0]
	b. to the roof?	yes [0] no [0.9]
B-7	Is the dwelling located on a 3:1 slope or steeper with wood frame braces or tension only braces below the lower level diaphragm	yes? [2.5] no? [0]
B-8	Are the number of stories	a. one (1)? [0] b. two (2)? [1.8] c. 3 or more? [3.6]
B-9	The main level floor is supported on a	
	a. cripple stud wall with no vehicle retrofit?	[3.8]
	b. retrofitted cripple wall?	[1.0]
	c. no cripple wall?	[0]

Total

Sample Questions: (from each category)

A-6	For a raised foundation system		
	a. is the mudsill of the exterior footings bolted to the foundation with bolts spaced 72" or less, or retrofitted?		[0]
	b. bolted with > 72" spacing?		[1.5]
	c. are there no foundation bolts?		[4.2]
B-7	Is the dwelling located on a 3:1 slope or steeper with wood-frame braces or tension only braces below the lower level diaphragm?	Yes No	[2.5] [0]
C-2	Does the water heater have approved anchor straps and flexible water/gas connections?	Yes No	[0] [1.3]
D-2	For a cut-and-fill "transition" lot, was the lot developed		
	a. before 1963?		[2.6]
	b. 1964 or later?		[1.3]
	c. lot is not from cut-and-fill?		[0]
E-5	Is there any evidence of stucco detachment? (bowing of stucco, corroded chicken wire, finished grade above the bottom of the stucco	Yes No	[4.0] [0]

Summary:

The ATC-50 Seismic Grading Form developed by the authors based on the earthquake loss data and rational engineering is a much-needed efficient tool. The form will allow a homeowner, the lender and the insurance company to better understand the seismic vulnerability and potential damage for a detached wood-frame dwelling for use with incentives. The form will also clearly identify the deficiencies in the dwelling for the homeowners to upgrade their properties and thus minimize the hazard and economic loss from the future ground shaking.

References

1. Frankel, Arthur, et al, National Seismic – Hazard Maps: Documentation June 1996, Open-file report 96-532, U.S. Department of Interior, U.S. Geological Survey.

2. International Conference of Building Officials, Uniform Building Code, 5360 South Workman Mill Road, Whittier, California 90601 (1997).

3. Working Group on California Earthquake Probabilities, "Seismic Hazards in Southern California: Probable Earthquakes, 1994-2024," Bulletin of the Seismological Society of America (Volume 85 Bulletin No. 2, April, 1995).

4. Eguchi, Ronald T., Kenneth W. Campbell and John H. Wiggins, A Survey of Expert Opinion on Active and potentially – Active Faults in California, Nevada, Arizona and Northern Baja California, J.H. Wiggins Company, U.S. Geological Survey, Contract No. 14-08-0001-16825 (February, 1979).

5. Al-Faris, Khalid and Bernardo Tan, Northridge Earthquake Insurance Loss Report, State of California, Department of Insurance (August, 1996).

6. Wiggins, John H., et al, Seismic Safety Study City of Los Angeles, J. H. Wiggins Company, Technical Report No. 74-1199-1, prepared for the Planning Department, City of Los Angeles (30 April 1974).

7. Wiggins, John H., Joseph G. Hirschberg and Allen J. Bronowicki, Budgeting Justification for Earthquake Engineering Research, J. H. Wiggins Company, Technical Report No. 74-1201-1, prepared under National Science Foundation, Grant #GI-41071 (May 10, 1974).

8. Ziony, J. I., Editor, Evaluating Earthquake Hazards in the Los Angeles Region – An Earth-Science Perspective, U.S. Geological Survey, Professional Paper 1360 (1985)

9. City of Los Angeles / SEAOSC Task Force Reports of Northridge EQ – Wood-frame

10. EQE International, Inc. and the Geographic Information Systems Group of the Governor's Office of Emergency Services, 1995, *The Northridge Earthquake of January 17, 1994: Report of Data Collection and Analysis, Part A: Damage and Inventory Data*, for the Governor's Office of Emergency Services of the State of California.

11. McClure, F.E. and D.L. Messinger, 1973, *Performance of Single Family Dwellings in the San Fernando Earthquake of February 9, 1971*, prepared for the U.S. Department of Commerce, National Oceanic and Atmospheric Administration and supported by the U.S. Department of Housing and Urban Development, Washington, D.C.

12. Neter, John, William Wasserman and Michael H. Kutner, 1985, *Applied Linear Statistical Models*, Homewood, Illinois; Irwin.

13. Steinbrugge, K. V., 1982, *Earthquakes, Volcanoes, and Tsunamis: An Anatomy of Hazards*, New York City: Skandia American Group.

14. Taylor, Craig E., Ronald T. Eguchi and S.E. Chang, 1998, "Updating Real-Time Earthquake Loss Estimates: Methods, Problems, and Insights," *Proceedings of the Sixth U.S. National Conference on Earthquake Engineering*, Seattle, Washington, May 31 – June 4, 1988, published by the Earthquake Engineering Research Institute.

15. Wiggins, John H. and Craig Taylor, 1986, *Damageability of Low-Rise Construction: Data Bases; Categorization Techniques; Rating Procedures; Proposed Survey Procedures*, Long Beach, CA: NTS Engineering for the National Science Foundation.