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Published by Elsevier Science Ltd 1996
Paper No.1971. (quote when citing this article)
Eleventh World Conference on Earthquake Engineering
ISBN: 0 08 042822 3

SCREENING METHODOLOGY FOR THE SEISMIC ASSESSMENT OF PARTICULAR BUILDINGS IN LOS ALAMOS NATIONAL LABORATORY

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ABSTRACT

According to the Los Alamos National Laboratory's (LANL) Seismic Program Plan, a seismic assessment program was elaborated to provide a rational, objective, and uniformly applied methodology for screening buildings and facilities at LANL for finding its seismic capacity and potential dynamic hazards. Following a general plan proposed by Dr. Otto Fritz, the screening method in its basic formulation was established by LANL's engineers (FSS-6) in collaboration with the Johnson Controls World Services Engineering Branch.

This methodology is based on the experience and results obtained from criteria applied by the author in other earthquake regions, principally in Mexico and Germany. With minor adaptations to the Los Alamos area, the previous knowledge was employed in the seismic assessment of 479 buildings and structures of diverse shape and materials to determine the seismic capacity of the unit or its component sectors.

The work is organized in several major divisions: 1. Introduction; 2. Data obtained in situ by trained inspectors; 3. Data obtained from original and as-built drawings and all available additional material; 4. Accomplishment of the requirements contained in FEMA-154; 5. Calculation of the Seismic Shear Forces; 6. Calculation of the Lateral Base Shear Capacity of the building; 7. Determination of the Seismic Security Coefficient of the building or its sectors; 8. Consideration of results; and 9. Conclusion.

KEYWORDS

Seismic assessment; shear capacity of buildings; construction materials, reduced stresses.

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Introduction

According to the Los Alamos National Laboratory Seismic Program Plan, a seismic assessment system was developed to provide a rational, objective and uniformly applied methodology for screening buildings at Los Alamos National Laboratory (LANL) for determining its seismic capacity and potential dynamic hazards. Following a general procedure proposed by Dr. Otto Fritz, based on his previous experience and results, a screening method in its basic formulation was adapted by LANL's Engineering Services Team of the Facility Delivery Project Group (FSS-6), in collaboration with the Johnson Controls World Services (JCWS) Design Engineering Branch.

This basic adapted methodology satisfies the requirements of the Federal Emergency Management Agency FEMA-154 "Rapid Visual Screening of Buildings for Potential Seismic Hazards: A Handbook," also known as ATC-21, which is a speedy screening method that gives pass/fail results on seismic safety.

From the beginning and based on former results from structures damaged by earthquakes, LANL engineers became aware of the deficiencies of this method. First, the FEMA-154 "sidewalk assessment" does not provide sufficient insight into the resisting structure of the building in order to determine its seismic adequacy. To remove the subjectivity of the collected data based on different points of view of inspection personnel, a unique criteria for the screening in situ was established to take advantage of having construction drawings and calculations for most, if not all, LANL buildings.

Both improvements remove the principal defects of FEMA-154. The new LANL/JCWS Seismic Screening Assessment Method is an adapted version of Dr. Fritz's original procedure and permits an inexpensive and accurate way for the assessment of building seismic safety with remarkably consistent results.

Data Obtained In Situ by Trained Inspectors

The basic scoring concepts of the FEMA-154 standard are considered in the enhanced LANL/JCWS methodology. The in situ structural field inspection gives a true account of internal details of the building in which joints, continuity, and connections are evaluated together with the aid of drawings and original basic information. These advantages, in conjunction with the judgement of a Professional Engineer, eliminates completely the original subjectivity of FEMA-154. The general procedure was used extensively by Dr. Fritz in Mexico for several years with outstanding results in terms of time, reliability, effort, and cost reduction.

The "Seismic Assessment Survey-Field Data" gives us the following information:
Data General: Name of inspector; inspection date, in situ; Technical Area (TA) in which the building is located; building number, according to the catalog; sector of the building; building title or name; and name and telephone of the Building Manager.

Technical Data: Building type, according to the ATC, 1987. Materials taken into consideration: wood, steel, and concrete. Information about the population and occupancy is also required. The design data gives information about the used codes. The field sheet is given in Figure 1.

Data Obtained from Original and As-built Drawings and all Available Additional Material

The subjectivity and ambiguities of FEMA-154 (ATC-21) are minimized by providing standardized, quantified criteria as the basis for applying the Performance Modification Factors.

The information provided by the construction drawings of the existing buildings, and checked in situ, was from the highest value to determine its real state and possible performance.

Because many buildings at LANL have been modified and expanded over the years, several different building types and construction dates may be present in one building. Some large buildings have expansion joints separating portions of the original structure or additions to it.

The behavior of the buildings after being sectored was taken in account for the structural analysis, so most of them were divided in several sectors.

For each building a Sector A was assigned. Additional sectors were built later or separated by construction joints. In these cases, the additional sectors were named B, C, D, etc. A complete two-direction analysis was made for each sector. All dimensions were field-verified by the inspectors, giving an accurate picture of the building dimensions and components. When drawing discrepancies were found, the actual conditions were recorded in the field and used for the evaluation of the seismic capacity of the structure.

The building manager allowed access to the buildings, and, in many cases, provided additional information on the configuration and any problems in the building.

Thus, all sectors of each building were correctly identified and deficiencies were noted. Many times, the column or wall connection to the basement or foundation could be exposed, allowing verification of the anchorage. This allowed a true evaluation of the shear capacity of the structure; the information required was the real areas of the resisting elements like columns and walls to oppose to the action of the seismic shear force acting on the connection level of the super and infrastructure.

According to the building type, a basic score is given from which the modifiers (values which represent negative elements as poor condition, vertical of plan irregularities, pounding, etc.) are subtracted to give a final score.

Accomplishment of the Requirements Contained in FEMA-154

Structural Scores and Modifiers are given in Figure 2.

Data to be filled in the Seismic Assessment Survey-Field Data form includes several performance factors as defined before.

Buildings which receive a filing ATC-21 score of less than 2.0 on the initial survey will be subject to a more detailed analysis to determine the structural adequacy of the building. On those buildings, no preliminary strength determination will be performed. A detailed analysis is not part of the screening phase of this program.

Calculation of the Seismic Shear Forces

For buildings with an ATC-21 score of 2.0 or more, a seismic shear force was calculated. An evaluation of the actual loads on the building was executed in all cases, based on all available drawings and the information gained during the field observations. Known construction materials and equipment weights used in the calculation, from roof, floors, walls, columns and eventual steel or concrete frames conformed the weight of the building or sector.

The horizontal shear force at the connection between the foundation and the superstructure, using a seismic coefficient, can be calculated according to the formula.

Force = Mass x Acceleration, or

$V = c\,W/g$, in which:

V = Seismic shear force, pounds,
W = Weight of building, pounds,
g = Gravity acceleration, 32.2 in/sq sec.
c = Seismic coefficient = 0.2g

The coefficient, c = 0.2g was carefully selected after taking into account all provisions in the Department of Energy and NEHRP standards and the Uniform Building Code. It was found that c = 0.2g accounts for behavior of all typical structure types and is conservative in most cases.

Thus, the seismic force used at Los Alamos is calculated according to the formula $V = 0.2W$.

Calculation of the Lateral Base Shear Capacity of the Building

All components of the building or sector, connected rigidly to the foundation, contribute to the structural capacity to resist the seismic impulse.

Typically we have: concrete or masonry in walls or columns; bolts in steel or wood construction; welded sections in steel construction.

Always, we will have a capacity, R, formed by an area and a stress, or sum of several areas multiplied by stresses, contributing to the structural capacity to resist the seismic impulse R = Areas x Stresses, for the equilibrium, $R >= V$.

The unit shear stresses used in Los Alamos were calculated and observed in failed structures so that a structural damage of failure could be prevented. Most of the values were determined after the Mexico City earthquake of September 1985.

The unit shear capacity of diverse construction materials are given below:

All masonry, including grouted cells	v = 21 psi
Concrete wall with no end columns	v = 171 psi
Concrete wall with column at one end	v = 229 psi
Concrete wall with columns at both ends	v = 286 psi
Concrete column with H/d>10	v = 62 psi
Concrete column with 6<H/d<=10	v = 100 psi

Concrete column with 2<H/d<=6	v = 143 psi
Concrete column with H/d<=2	v = 214 psi
Steel column or anchor bolt	v = 0.2 Fy

In the above values,

H	=	clear height of the concrete column,
d	=	least thickness of the concrete column,
Fy	=	steel yield stress.

Determination of the Seismic Security Coefficient of the Building or its Sectors

The Shear Seismic Coefficient (SSC) is a measure of the building's resistance to a lateral shear load caused by a 0.2g horizontal acceleration.

SSC = R/V> = 1.0, passed.

Since a building's resistance, R, is calculated for two perpendicular directions, two SSC values can be established for each building or sector of it. Only one, the lowest, shows the building's real resistance.

All buildings with a SSC = R/V> = 1.0, passed the second stage of screening.

Consideration of Results

The results of the seismic screening, as of August 31, 1995 completion, are as follows:

Buildings Completed:	479
Sectors Completed	849
Buildings Scheduled through August 31:	427
Buildings in Excess:	52
Working Days:	162
Final Number of Buildings in Excess:	20

Ratio Sectors/Completed Buildings = 849/479 = 1.7724

Results of the Screening

First Stage:
LANL, (ATC-21) Score Summary:

LANL Score>=2.0,	642 units	(75.62%)
LANL Score<=2.0,	207 units	(24.38%)

Second Stage:

Seismic Shear Score>=1,	455 units	(70.87%)
Seismic Shear Score<1,	187 units	(29.13%)
No Seismic Shear Score, (No connection to foundation),	125 units	(19.47%)
Total possible Shear Score passing,	580 units	(90.34%)

Buildings Intended to Review	459
Buildings Completed:	479
Buildings Remaining until September 30, 1995:	00
Buildings in Excess	20

Total Advance of Completed Buildings: 479/459 = 1.044

Budget Utilized Until This Moment = 95%

Conclusion

Using the methodology developed by Dr. Otto Fritz, adapted by LANL and JCWS engineers, the task for screening 459 buildings were completed in a shorter time than scheduled.

In 32 working weeks, instead of 34, a grand total of 479 buildings, with 849 sectors were completed, at a cost of 91% of the accepted budget. The rest of our budget money was used to prepare a comparison between our method and its results, with the manuals of FEMA-154 and FEMA-178.

As a final word, it can be stated that, by using this method, we save time, effort, and money to get reliable results of the seismic capacity of buildings.

Figures 1 and 2 are presented on the following page:

I want to express my thanks to Steve Dickson, who revised the manuscript and made useful suggestions and led the capable team of inspectors who made this task possible. Also, thanks to Douglas Volkman, Miles Brittelle, Leon Kantola and Roger Perkins, all of Los Alamos National Laboratory, for permanent support of this work.

Los Alamos, New Mexico, February 14, 1996.

Dr. Gustavo Otto Fritz-de la Orta, P.E.

Seismic Assessment Survey - Field Data

Inspector: ______________________ **Date:** ______________

TA: ________ **Sector:** ________ **Bldg. Mgr.:** ______________________ **Phone:** ________

Bldg.: ______ **Bldg Title:** ____

Structure Description ____

____

Building Type:

Wood	Steel				Concrete		St. or Conc.		Precast		Masonry	
(All) W	MRF S1	BR S2	LM S3	RCSW S4	MRF C1	SW C2	URM S5	INF C3	TU PC1	Other PC2	RM	URM

Population: 0-10 / 10-100 / 100+

Occupancy: Office / Lab / Shop / Storage / Utility / __________

Design Date __________ **Post-Benchmark:** Yes / No

Benchmark Year __________

C Numbers: ______________________

Size
Length ______________ft
Width ______________ft
Area ______________sq ft
Height ______________ft
Stories ______________

High Rise
H >= 8 Stories
H >= 100 ft
H/L >= 5

Poor Condition
Diagonal Shear Cracks
Extensive Corrosion
Rot or Pest Damage
Inferior Mortar Joints
Lack of Adequate Bearing
Vertical Foundation Movement
Column Tilting
No Foundation Attachment
____

Vertical Irregularity
Vertical Geometric Irregularity
In-Plane Offset
Weak Story
Weight Irregularity
Sloped Walls or Columns
Sloped Grade

Plan Irregularity
Reentrant Corners
Attached Sector > 20%
Aspect Ratio
Large Tilt-up Building
Diaphragm Discontinuity
Out-of-Plane Offset
Nonparallel System

Soft Story
Long Columns
Missing Columns

Torsion
Eccentricity > 5% by Inspection
Eccentricity > 5% by Calculation

Large Heavy Cladding
>15 psf Panels
on Frame Type Building

Short Column
Partial Height Infill Walls
Intermediate Beams

Soil Type
Soft
Medium
Rigid

Pounding
d ______________ft
H ______________ft
d/H ______________

Scores: ***ATC-21:*** ______________
Shear Resistance: ______________

Figure 1: Field Data Sheet

BUILDING TYPE	W	S1 MRF	S2 BR	S3 LM	S4 RCSW	C1 MRF	C2 SW	S5/C3 INF	PC1 TU	PC2	RM	URM
DESCRIPTION	Wood or Steel Stud	Steel Moment Resisting Frame	Steel Braced Frame	Pre-engineered Steel Building	Steel Frame w/ Concrete Shear Walls	Concrete Moment Resting Frame	Concrete Shear Wall	Steel or Concrete Frame w/ Masonry Infill	Precast Concrete Tilt-up Panels	Precast Concrete Frame	Reinforced Masonry	Unreinforced Masonry
Basic Score	6.0	4.0	3.0	6.0	4.0	3.0	3.5	2.0	3.5	2.0	3.5	2.0
High Rise	N/A	-1.0	-0.5	N/A	-1.0	-0.5	-1.0	-1.0	N/A	0.0	-0.5	-0.5
Poor Condition	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Vertical Irregularity	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-0.5	-1.0	-1.0	-1.0	-0.5	-1.0
Soft Story	-1.0	-2.0	-2.0	-1.0	-2.0	-2.0	-2.0	-1.0	-1.0	-1.0	-2.0	-1.0
Torsion	-1.0	-2.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0	-1.0
Plan Irregularity	-1.0	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-1.0	-1.0	-1.0	-1.0
Pounding •	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Heavy Cladding	N/A	-2.0	N/A	N/A	N/A	-1.0	N/A	N/A	N/A	-1.0	N/A	N/A
Short Columns	N/A	N/A	N/A	N/A	N/A	-1.0	-1.0	-1.0	N/A	-1.0	N/A	N/A
Post Benchmark Year	+2.0 1949	+2.0 1976	+2.0 1988	+2.0 1988	+2.0 1976	+2.0 1976	+2.0 1976	N/A	+2.0 1973	N/A	+2.0 1976	N/A

• Pounding Modifier only applicable if one or more adjacent buildings or sectors is Building Type S1, S2, S3, S4, C1, or PC2.

Figure 2: Structural Scores and Modifiers