Ciencia y Sociedad
ISSN: 0378-7680
dpc@mail.intec.edu.do
Instituto Tecnológico de Santo Domingo
República Dominicana

Hernández, José Daniel Benjamín; Lockhart Castro, Sidney Antonio
Metodología para la evaluación de la vulnerabilidad sísmica de edificaciones de hormigón armado existente
Ciencia y Sociedad, vol. XXXVI, núm. 2, abril-junio, 2011, pp. 256-275
Instituto Tecnológico de Santo Domingo
Santo Domingo, República Dominicana

CIENCIA Y SOCIEDAD
Volumen XXXVI, Número 2
Abril-Junio 2011

METODOLOGÍA PARA LA EVALUACIÓN DE LA VULNERABILIDAD SÍSMICA DE EDIFICACIONES DE HORMIGÓN ARMADO EXISTENTE

(Methodology for the evaluation of seismic vulnerability in reinforced concrete buildings)

José Daniel Benjamín Hernández*
Sidney Antonio Lockhart Castro**

RESUMEN
La evaluación de la vulnerabilidad sísmica debe iniciarse con un método cualitativo y de no cumplirse este, entonces usar el método cuantitativo, el cual va acompañado de un análisis más completo, ya que puede contemplar tanto un análisis estructural Lineal o No Lineal, para la determinación del Reforzamiento o no de la edificación.

PALABRAS CLAVES
Vulnerabilidad sísmica, reforzamiento, estructuración, daños, colapso.

ABSTRACT
The evaluation of seismic vulnerability must begin with a qualitative method and if this is not fulfilled, then we have to use the quantitative method, which is accompanied by a more complete analisys, It can include both a structural analysis linear or nonlinear, for the determination of the reinforcement of the building.

KEY WORDS
Seismic vulnerability, reinforcement, structure, damage, collapse.

---

* Área de Ingenierías, Instituto Tecnológico de Santo Domingo, INTEC. República Dominicana.
E-mail: josbenj@gmail.com

** Grupo Empresarial Lockhart, Santo Domingo Domingo, República Dominicana.
E-mail: grupo.lockhart@gmail.com

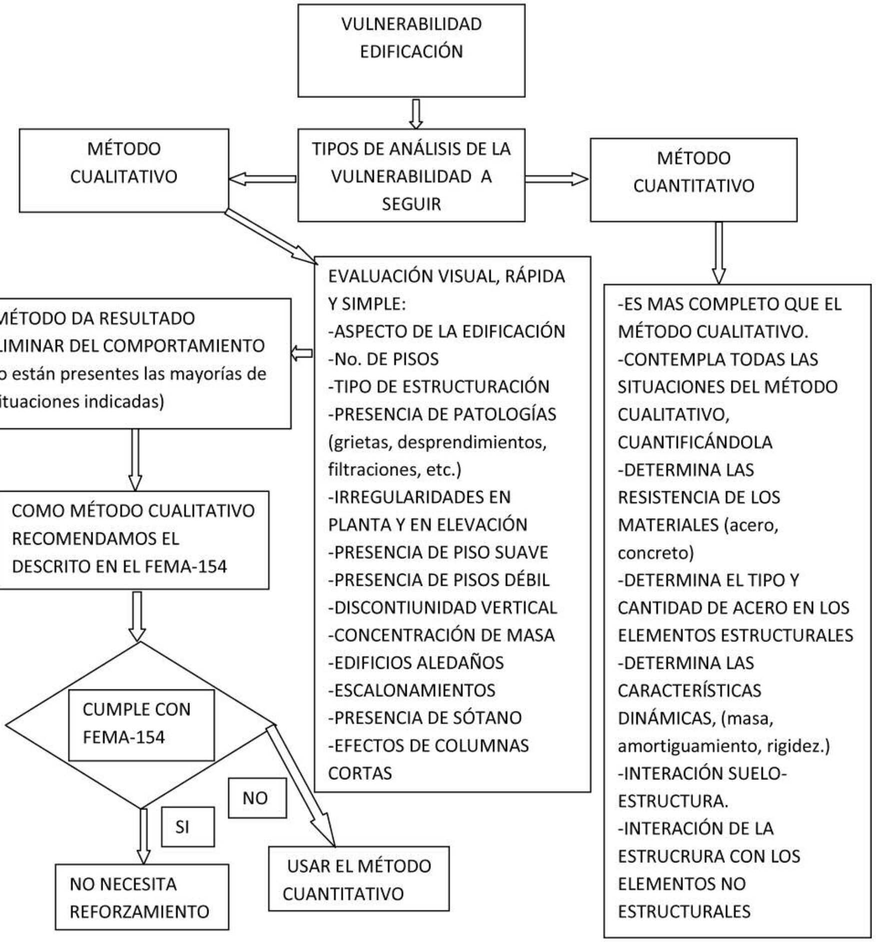
INTRODUCCIÓN

Para la realización de un análisis sismo-resistente a una edificación de hormigón armado existente, hay que hacer un análisis de vulnerabilidad sísmica, para determinar si se debe o no reforzar la edificación para que tenga un comportamiento adecuado frente a un evento sísmico.

Primero debemos conocer qué se entiende por vulnerabilidad. Esta no es más que la debilidad que presenta una edificación u objeto frente a un evento que representa una peligrosidad, el cual al presentarse le generará daños.

Es importante realizar una evaluación de la vulnerabilidad sísmica que refleje la situación real de la edificación para enfrentar un sismo.

MATRIZ DE ANÁLISIS DE LA VULNERABILIDAD SÍSMICA DE UNA EDIFICACIÓN

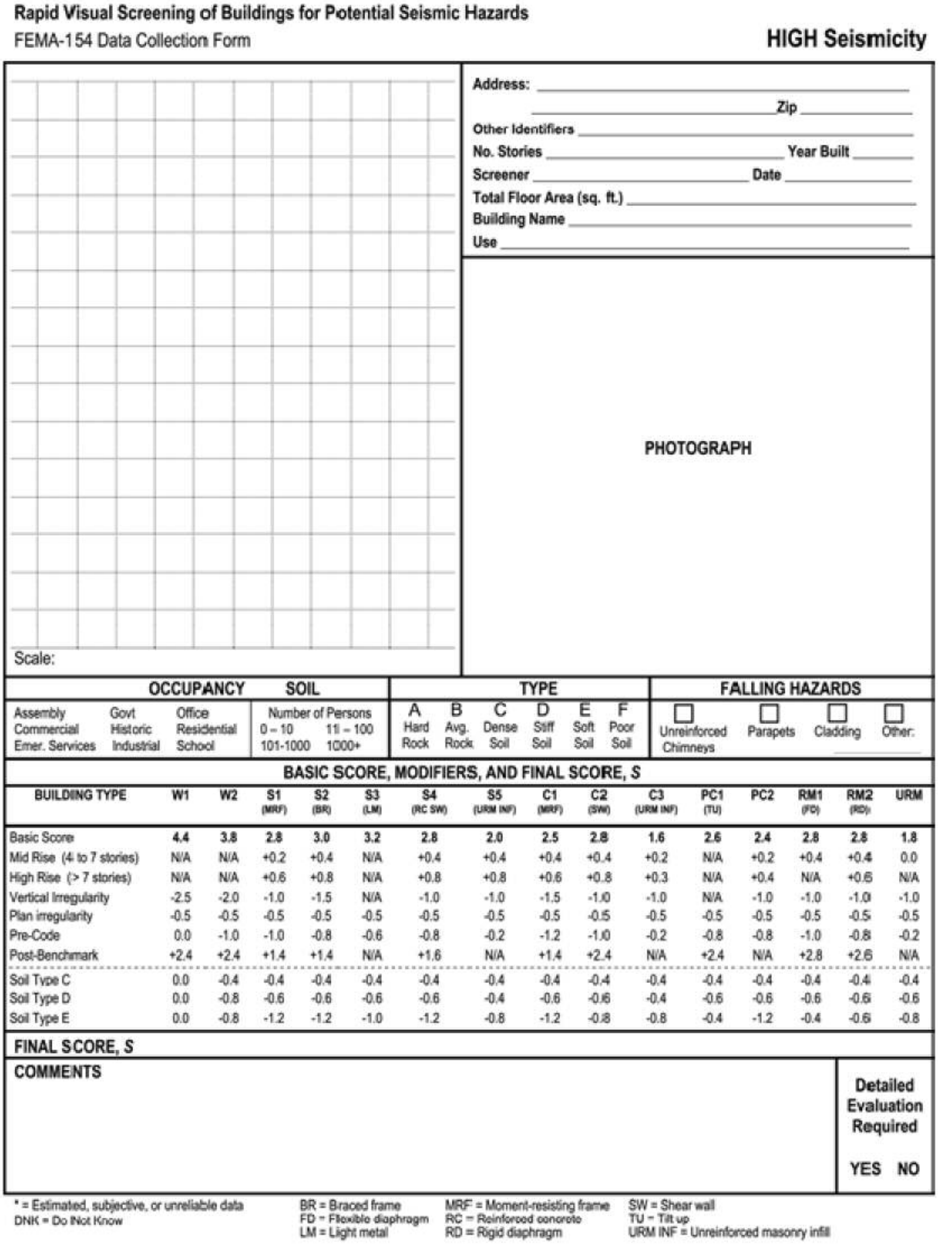


MÉTODO USADO EN EL FEMA -154

El método usado en los Estados Unidos por el Federal Emergency Management Agency (FEMA), conocido como FEMA-154, es un método cualitativo, el cual para la determinación de si se reforzará la edificación lo hace a través de un índice, si el resultado de la evaluación es menor o igual que dos (≤ 2) hay que usar un método más detallado que conlleva el análisis de la edificación con análisis primeramente lineal, si cumple no hay que reforzar, si no cumple hay que hacer un análisis no lineal de la edificación, si cumple no hay que reforzar y si no cumple definitivamente hay que reforzarla. Si el índice de la metodología es mayor o igual que dos (≥ 2), no necesita reforzamiento, el índice 2 significa que la edificación tiene una probabilidad de 1 a 100 de que colapse.

El método maneja un formulario que contempla una descripción de la edificación que incluye: localización, número de pisos, año de construcción, área de construcción, nombre del edificio, uso, foto de la edificación, un espacio para esquematizar irregularidades tanto en planta como en elevación. También posee unos recuadro donde se señalará el uso, la cantidad de persona que la ocuparán, los tipos de suelo, los tipos de elementos no estructurales, 15 estructuraciones a contemplar, las cuales presentaremos con los índices básicos de acuerdo al riesgo sísmico de la localidad, luego presenta un recuadro donde están los factores de ajuste del índice básicos por las siguientes características: altura media (4 – 7 niveles), gran altura (≥ 8 niveles), irregularidades en elevación, irregularidades en planta, ajuste por el año de la edificación ante de uso de la primera normativa, ajuste por el año de construcción después de la normativa vigente. Para estas evaluaciones estamos suministrando las informaciones para su uso, aunque está hecha para los Estados Unidos, vamos a extrapolar esas informaciones para la Republica Dominicana. Luego presenta el cuadro de ajuste por el tipo de suelo, y por último se determina el índice final a través de una suma algebraica de los valores involucrados. Conocido este índice final se determina si no se necesita reforzar la edificación o si hay que utilizar otro método como explicamos anteriormente. Presentaremos como ejemplo del uso del método cualitativo FEMA-154, la edificación objeto del trabajo realizado.

FORMULARIO SUMINISTRADO POR EL FEMA-154



Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA-154 Data Collection Form

HIGH Seismicity

Address: ____________________

____________________ **Zip** __________

Other Identifiers ____________________

No. Stories ____________________ **Year Built** __________

Screener ____________________ **Date** __________

Total Floor Area (sq. ft.) ____________________

Building Name ____________________

Use ____________________

Scale:

PHOTOGRAPH

OCCUPANCY **SOIL** **TYPE** **FALLING HAZARDS**

Assembly Commercial Emer. Services	Govt Historic Industrial	Office Residential School	Number of Persons 0 – 10 11 – 100 101-1000 1000+	A Hard Rock	B Avg. Rock	C Dense Soil	D Stiff Soil	E Soft Soil	F Poor Soil	☐ Unreinforced Chimneys ☐ Parapets ☐ Cladding ☐ Other:

BASIC SCORE, MODIFIERS, AND FINAL SCORE, *S*

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	4.4	3.8	2.8	3.0	3.2	2.8	2.0	2.5	2.8	1.6	2.6	2.4	2.8	2.8	1.8
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	+0.2	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	-1.0	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	-0.4	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8

FINAL SCORE, *S*

COMMENTS

Detailed Evaluation Required

YES NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
W1 Light wood frame residential and commercial buildings equal to or smaller than 5,000 square feet		H = 2.8 M = 5.2 L = 7.4	• Wood stud walls are typically constructed of 2-inch by 4-inch vertical wood members set about 16 inches apart (2-inch by 6-inch for multiple stories). • Most common exterior finish materials are wood siding, metal siding, or stucco. • Buildings of this type performed very well in past earthquakes due to inherent qualities of the structural system and because they are lightweight and low rise. • Earthquake-induced cracks in the plaster and stucco (if any) may appear, but are classified as non-structural damage. • The most common type of structural damage in older buildings results from a lack of connection between the superstructure and the foundation, and inadequate chimney support.
W2 Light wood frame buildings greater than 5,000 square feet		H = 3.8 M =4.8 L = 6.0	• These are large apartment buildings, commercial buildings or industrial structures usually of one to three stories, and, rarely, as tall as six stories.

Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes (Continued)

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
S1 Steel moment-resisting frame		H = 2.8 M = 3.6 L = 4.6	• Typical steel moment-resisting frame structures usually have similar bay widths in both the transverse and longitudinal directions, around 20-30 ft. • The floor diaphragms are usually concrete, sometimes over steel decking. This structural type is used for commercial, institutional and public buildings. • The 1994 Northridge and 1995 Kobe earthquakes showed that the welds in steel moment- frame buildings were vulnerable to severe damage. The damage took the form of broken connections between the beams and columns.
S2 Braced steel frame	  Zoom-in of upper photo	H = 3.0 M = 3.6 L = 4.8	• These buildings are braced with diagonal members, which usually cannot be detected from the building exterior. • Braced frames are sometimes used for long and narrow buildings because of their stiffness. • From the building exterior, it is difficult to tell the difference between steel moment frames, steel braced frames, and steel frames with interior concrete shear walls. • In recent earthquakes, braced frames were found to have damage to brace connections, especially at the lower levels.

Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes (Continued)

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
S3 Light metal building		H = 3.2 M = 3.8 L = 4.6	• The structural system usually consists of moment frames in the transverse direction and braced frames in the longitudinal direction, with corrugated sheet-metal siding. In some regions, light metal buildings may have partial-height masonry walls. • The interiors of most of these buildings do not have interior finishes and their structural skeleton can be seen easily. • Insufficient capacity of tension braces can lead to their elongation and consequent building damage during earthquakes. • Inadequate connection to a slab foundation can allow the building columns to slide on the slab. • Loss of the cladding can occur.
S4 Steel frames with cast-in-place concrete shear walls		H = 2.8 M = 3.6 L = 4.8	• Lateral loads are resisted by shear walls, which usually surround elevator cores and stairwells, and are covered by finish materials. • An interior investigation will permit a wall thickness check. More than six inches in thickness usually indicates a concrete wall. • Shear cracking and distress can occur around openings in concrete shear walls during earthquakes. • Wall construction joints can be weak planes, resulting in wall shear failure below expected capacity.

Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes (Continued)

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
S5 Steel frames with unreinforced masonry infill walls		H = 2.0 M = 3.6 L = 5.0	• Steel columns are relatively thin and may be hidden in walls. • Usually masonry is exposed on exterior with narrow piers (less than 4 ft wide) between windows. • Portions of solid walls will align vertically. • Infill walls are usually two to three wythes thick. • Veneer masonry around columns or beams is usually poorly anchored and detaches easily.
C1 Concrete moment-resisting frames		H = 2.5 M = 3.0 L = 4.4	• All exposed concrete frames are reinforced concrete (not steel frames encased in concrete). • A fundamental factor governing the performance of concrete moment-resisting frames is the level of ductile detailing. • Large spacing of ties in columns can lead to a lack of concrete confinement and shear failure. • Lack of continuous beam reinforcement can result in hinge formation during load reversal. • The relatively low stiffness of the frame can lead to substantial nonstructural damage. • Column damage due to pounding with adjacent buildings can occur.

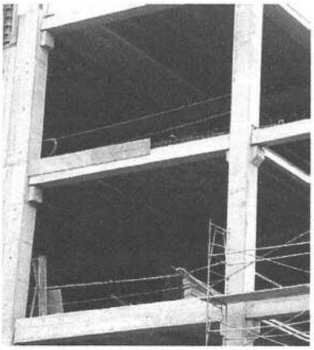
Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes (Continued)

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
C2 Concrete shear wall buildings		H = 2.8 M = 3.6 L = 4.8	• Concrete shear-wall buildings are usually cast in place, and show typical signs of cast-in-place concrete. • Shear-wall thickness ranges from 6 to 10 inches. • These buildings generally perform better than concrete frame buildings. • They are heavier than steel-frame buildings but more rigid due to the shear walls. • Damage commonly observed in taller buildings is caused by vertical discontinuities, pounding, and irregular configuration.
C3 Concrete frames with unreinforced masonry infill walls		H =1.6 M = 3.2 L = 4.4	• Concrete columns and beams may be full wall thickness and may be exposed for viewing on the sides and rear of the building. • Usually masonry is exposed on the exterior with narrow piers (less than 4 ft wide) between windows. • Portions of solid walls will align vertically. • This type of construction was generally built before 1940 in high-seismicity regions but continues to be built in other regions. • Infill walls tend to buckle and fall out-of-plane when subjected to strong lateral out-of-plane forces. • Veneer masonry around columns or beams is usually poorly anchored and detaches easily.

Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes (Continued)

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
PC1 Tilt-up buildings	  Partial roof collapse due to failed diaphragm-to-wall connection	H = 2.6 M = 3.2 L = 4.4	• Tilt-ups are typically one or two stories high and are basically rectangular in plan. • Exterior walls were traditionally formed and cast on the ground adjacent to their final position, and then "tilted-up" and attached to the floor slab. • The roof can be a plywood diaphragm carried on wood purlins and glulam beams or a light steel deck and joist system, supported in the interior of the building on steel pipe columns. • Weak diaphragm-to-wall anchorage results in the wall panels falling and the collapse of the supported diaphragm (or roof).

Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes (Continued)

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
PC2 Precast concrete frame buildings	 Building under construction  Detail of the precast components  Building nearing completion	H = 2.4 M = 3.2 L = 4.6	• Precast concrete frames are, in essence, post and beam construction in concrete. • Structures often employ concrete or reinforced masonry (brick or block) shear walls. • The performance varies widely and is sometimes poor. • They experience the same types of damage as shear wall buildings (C2). • Poorly designed connections between prefabricated elements can fail. • Loss of vertical support can occur due to inadequate bearing area and insufficient connection between floor elements and columns. • Corrosion of metal connectors between prefabricated elements can occur.

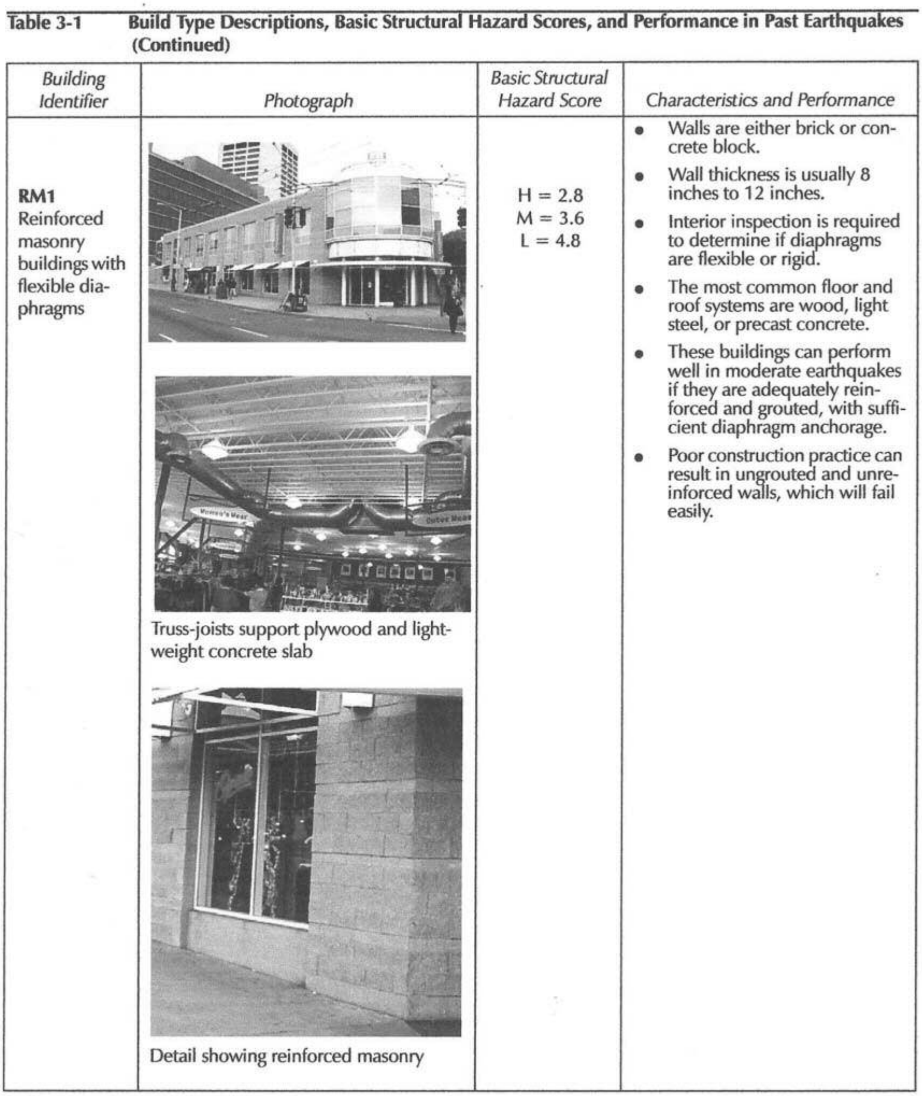
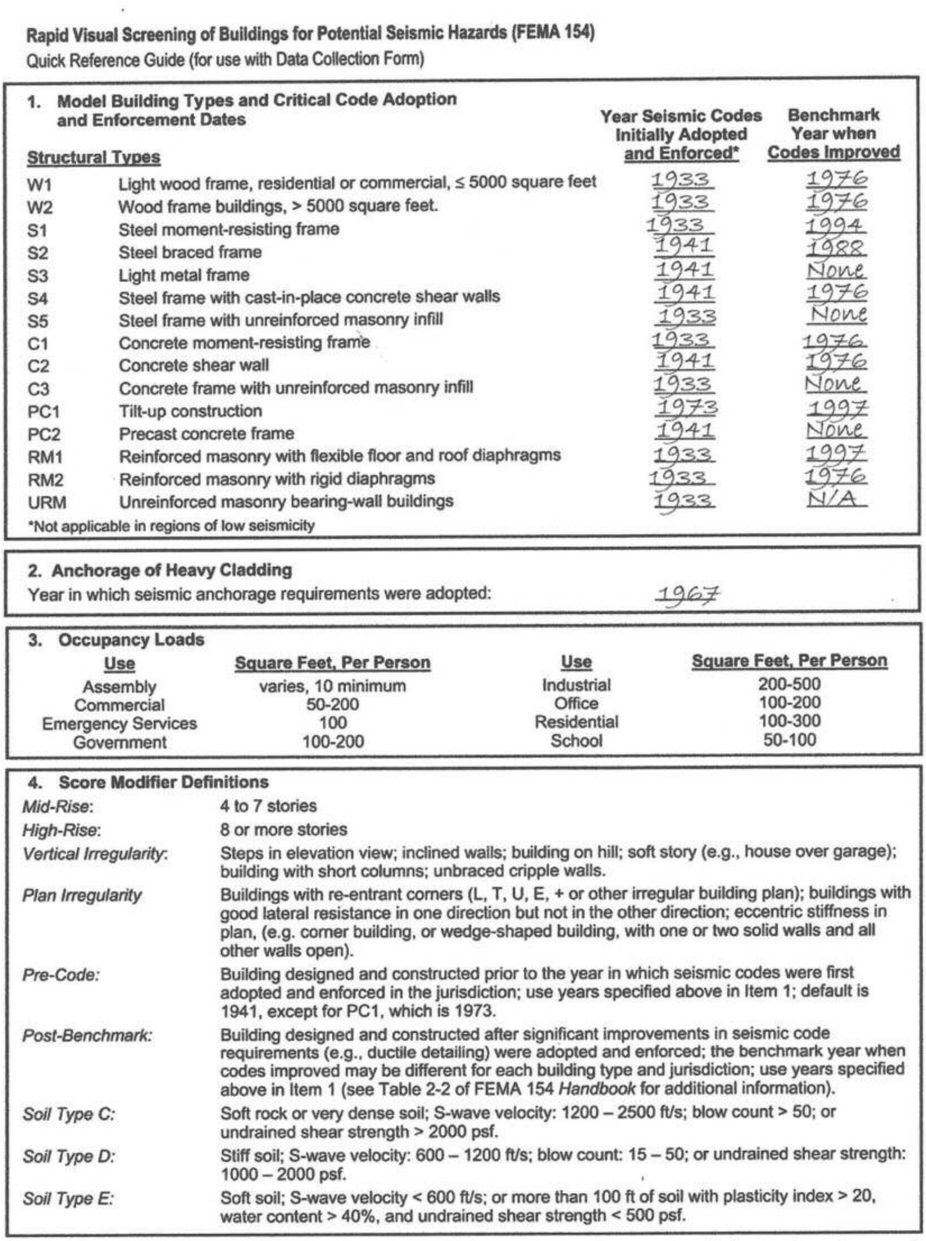


Table 3-1 Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes (Continued)

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
RM1 Reinforced masonry buildings with flexible diaphragms	Truss-joists support plywood and lightweight concrete slab Detail showing reinforced masonry	H = 2.8 M = 3.6 L = 4.8	• Walls are either brick or concrete block. • Wall thickness is usually 8 inches to 12 inches. • Interior inspection is required to determine if diaphragms are flexible or rigid. • The most common floor and roof systems are wood, light steel, or precast concrete. • These buildings can perform well in moderate earthquakes if they are adequately reinforced and grouted, with sufficient diaphragm anchorage. • Poor construction practice can result in ungrouted and unreinforced walls, which will fail easily.

Table 3-1 **Build Type Descriptions, Basic Structural Hazard Scores, and Performance in Past Earthquakes (Continued)**

Building Identifier	*Photograph*	*Basic Structural Hazard Score*	*Characteristics and Performance*
RM2 Reinforced masonry buildings with rigid diaphrams		H = 2.8 M = 3.4 L = 4.6	• Walls are either brick or concrete block. • Wall thickness is usually 8 inches to 12 inches. • Interior inspection is required to determine if diaphragms are flexible or rigid. • The most common floor and roof systems are wood, light steel, or precast concrete. • These buildings can perform well in moderate earthquakes if they are adequately reinforced and grouted, with sufficient diaphragm anchorage. • Poor construction practice can result in ungrouted and unreinforced walls, which will fail easily.
URM Unreinforced masonry buildings		H = 1.8 M = 3.4 L = 4.6	• These buildings often used weak lime mortar to bond the masonry units together. • Arches are often an architectural characteristic of older brick bearing wall buildings. • Other methods of spanning are also used, including steel and stone lintels. • Unreinforced masonry usually shows header bricks in the wall surface. • The performance of this type of construction is poor due to lack of anchorage of walls to floors and roof, soft mortar, and narrow piers between window openings.



Rapid Visual Screening of Buildings for Potential Seismic Hazards (FEMA 154)

Quick Reference Guide (for use with Data Collection Form)

1. Model Building Types and Critical Code Adoption and Enforcement Dates

Structural Types		**Year Seismic Codes Initially Adopted and Enforced***	**Benchmark Year when Codes Improved**
W1	Light wood frame, residential or commercial, ≤ 5000 square feet	1933	1976
W2	Wood frame buildings, > 5000 square feet.	1933	1976
S1	Steel moment-resisting frame	1933	1994
S2	Steel braced frame	1941	1988
S3	Light metal frame	1941	None
S4	Steel frame with cast-in-place concrete shear walls	1941	1976
S5	Steel frame with unreinforced masonry infill	1933	None
C1	Concrete moment-resisting frame	1933	1976
C2	Concrete shear wall	1941	1976
C3	Concrete frame with unreinforced masonry infill	1933	None
PC1	Tilt-up construction	1973	1997
PC2	Precast concrete frame	1941	None
RM1	Reinforced masonry with flexible floor and roof diaphragms	1933	1997
RM2	Reinforced masonry with rigid diaphragms	1933	1976
URM	Unreinforced masonry bearing-wall buildings	1933	N/A

*Not applicable in regions of low seismicity

2. Anchorage of Heavy Cladding

Year in which seismic anchorage requirements were adopted: 1967

3. Occupancy Loads

Use	Square Feet, Per Person	Use	Square Feet, Per Person
Assembly	varies, 10 minimum	Industrial	200-500
Commercial	50-200	Office	100-200
Emergency Services	100	Residential	100-300
Government	100-200	School	50-100

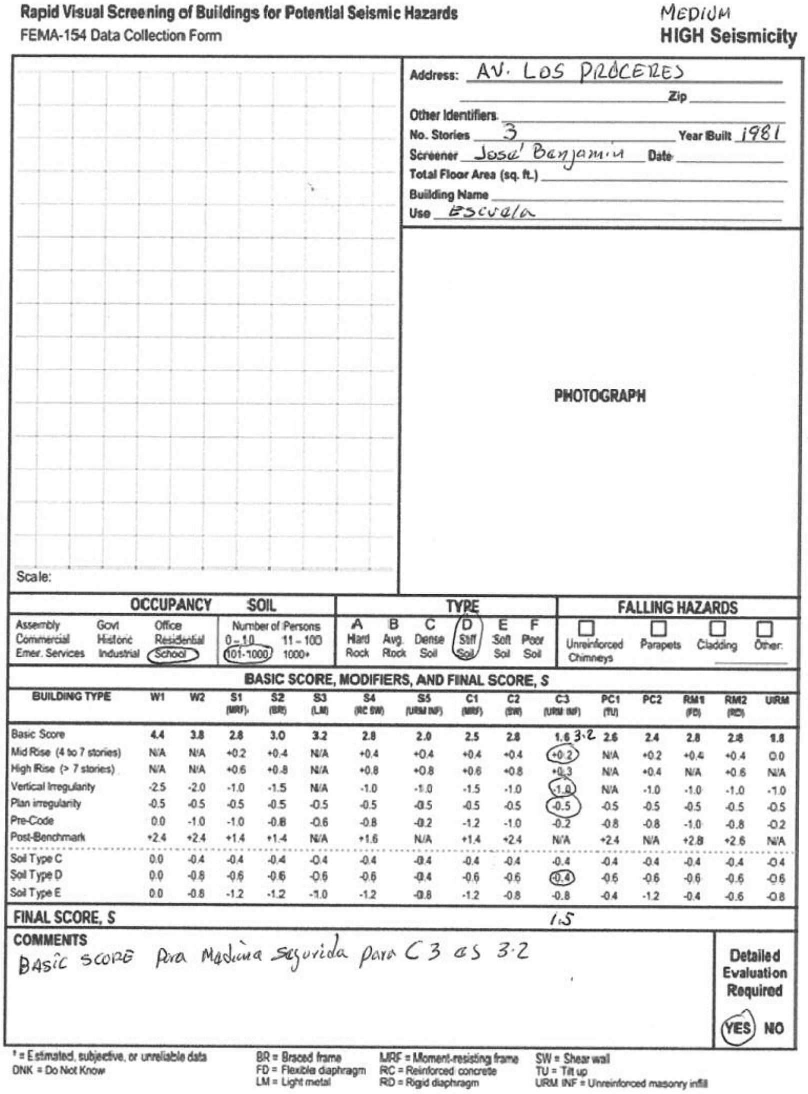
4. Score Modifier Definitions

Mid-Rise:	4 to 7 stories
High-Rise:	8 or more stories
Vertical Irregularity:	Steps in elevation view; inclined walls; building on hill; soft story (e.g., house over garage); building with short columns; unbraced cripple walls.
Plan Irregularity	Buildings with re-entrant corners (L, T, U, E, + or other irregular building plan); buildings with good lateral resistance in one direction but not in the other direction; eccentric stiffness in plan, (e.g. corner building, or wedge-shaped building, with one or two solid walls and all other walls open).
Pre-Code:	Building designed and constructed prior to the year in which seismic codes were first adopted and enforced in the jurisdiction; use years specified above in Item 1; default is 1941, except for PC1, which is 1973.
Post-Benchmark:	Building designed and constructed after significant improvements in seismic code requirements (e.g., ductile detailing) were adopted and enforced; the benchmark year when codes improved may be different for each building type and jurisdiction; use years specified above in Item 1 (see Table 2-2 of FEMA 154 *Handbook* for additional information).
Soil Type C:	Soft rock or very dense soil; S-wave velocity: 1200 – 2500 ft/s; blow count > 50; or undrained shear strength > 2000 psf.
Soil Type D:	Stiff soil; S-wave velocity: 600 – 1200 ft/s; blow count: 15 – 50; or undrained shear strength: 1000 – 2000 psf.
Soil Type E:	Soft soil; S-wave velocity < 600 ft/s; or more than 100 ft of soil with plasticity index > 20, water content > 40%, and undrained shear strength < 500 psf.

Figure 5-3 Quick Reference Guide for Anyplace USA showing entries for years in which seismic codes were first adopted and enforced and benchmark years.

APLICACIÓN METODOLOGIA DEL FEMA-154 A LA EDIFICACION QUE ESTAMOS ANALIZANDO

ANALISIS VULNERABILIDAD MODULO A



Rapid Visual Screening of Buildings for Potential Seismic Hazards
FEMA-154 Data Collection Form

MEDIUM
~~HIGH~~ **HIGH Seismicity**

Address: AV. LOS PRÓCERES
Zip
Other Identifiers
No. Stories 3 Year Built 1981
Screener José Benjamín Date
Total Floor Area (sq. ft.)
Building Name
Use Escuela

Scale:

PHOTOGRAPH

OCCUPANCY: Assembly, Govt, Office, Commercial, Historic, Residential, Emer. Services, Industrial, [✓ School]

SOIL — Number of Persons: 0 – 10, 11 – 100, [✓ 101-1000], 1000+

TYPE: A Hard Rock, B Avg. Rock, C Dense Soil, [✓ D Stiff Soil], E Soft Soil, F Poor Soil

FALLING HAZARDS: ☐ Unreinforced Chimneys ☐ Parapets ☐ Cladding ☐ Other:

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	C3 (URM INF)	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	4.4	3.8	2.8	3.0	3.2	2.8	2.0	2.5	2.8	1.6 3.2	2.6	2.4	2.8	2.8	1.8
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	[✓ +0.2]	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	[✓ -1.0]	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	[✓ -0.5]	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	[✓ -0.4]	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8
FINAL SCORE, S										1.5					

COMMENTS
BASIC SCORE Para Madiana segurida para C3 es 3.2

Detailed Evaluation Required
[✓ YES] NO

* = Estimated, subjective, or unreliable data
DNK = Do Not Know

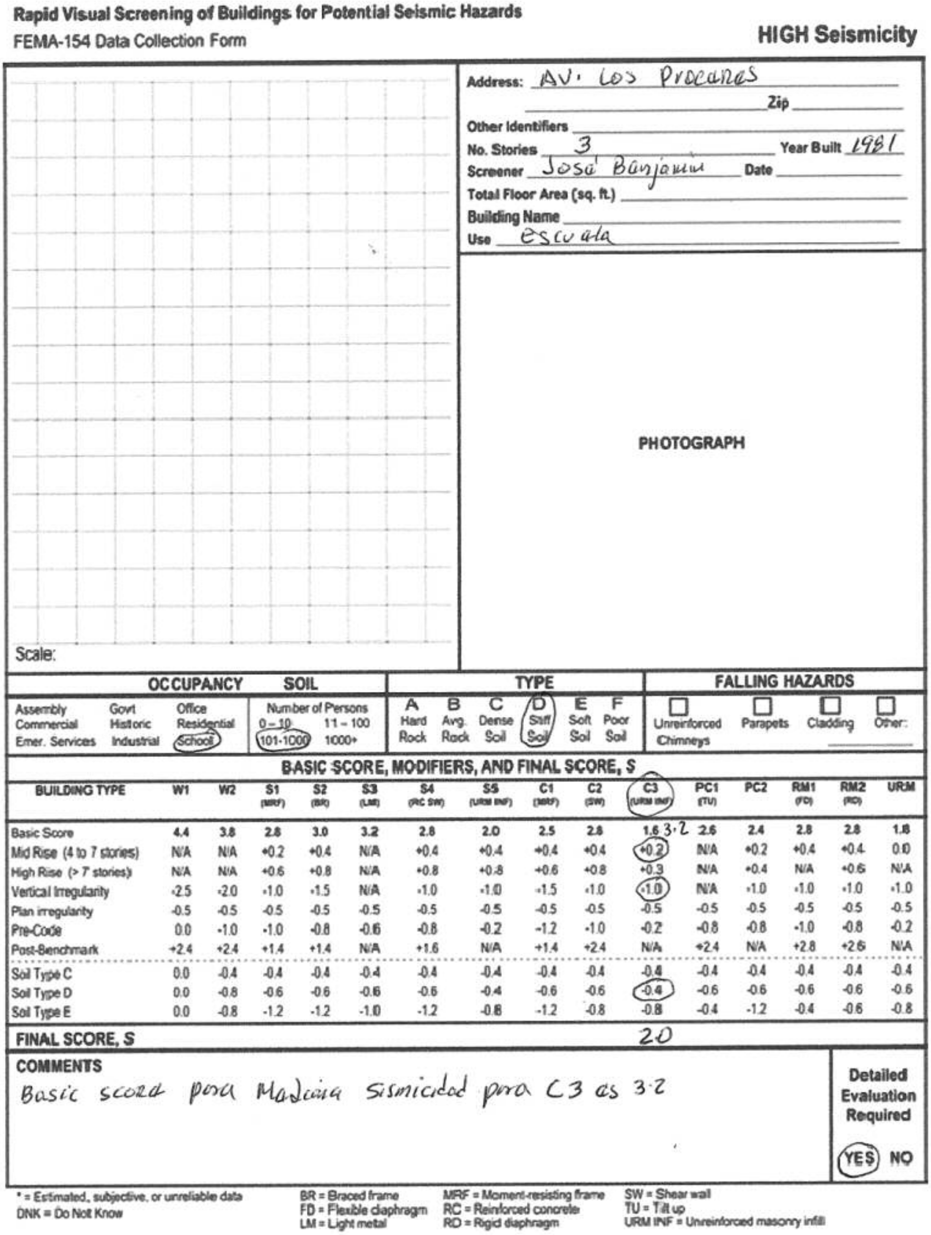
BR = Braced frame
FD = Flexible diaphragm
LM = Light metal

MRF = Moment-resisting frame
RC = Reinforced concrete
RD = Rigid diaphragm

SW = Shear wall
TU = Tilt up
URM INF = Unreinforced masonry infill

M

ANALISIS VULNERABILIDAD MODULO B



Rapid Visual Screening of Buildings for Potential Seismic Hazards

FEMA-154 Data Collection Form

HIGH Seismicity

Address: AV. Los Procanes

Zip

Other Identifiers

No. Stories 3 Year Built 1981

Screener José Benjamin Date

Total Floor Area (sq. ft.)

Building Name

Use escuela

Scale:

PHOTOGRAPH

OCCUPANCY

Assembly Govt Office

Commercial Historic Residential

Emer. Services Industrial [✓ School]

SOIL

Number of Persons

0 – 10 11 – 100

[✓ 101-1000] 1000+

TYPE

A Hard Rock B Avg. Rock C Dense Soil [✓ D Stiff Soil] E Soft Soil F Poor Soil

FALLING HAZARDS

☐ Unreinforced Chimneys ☐ Parapets ☐ Cladding ☐ Other:

BASIC SCORE, MODIFIERS, AND FINAL SCORE, S

BUILDING TYPE	W1	W2	S1 (MRF)	S2 (BR)	S3 (LM)	S4 (RC SW)	S5 (URM INF)	C1 (MRF)	C2 (SW)	[✓ C3 (URM INF)]	PC1 (TU)	PC2	RM1 (FD)	RM2 (RD)	URM
Basic Score	4.4	3.8	2.8	3.0	3.2	2.8	2.0	2.5	2.8	1.6 3.2	2.6	2.4	2.8	2.8	1.8
Mid Rise (4 to 7 stories)	N/A	N/A	+0.2	+0.4	N/A	+0.4	+0.4	+0.4	+0.4	[✓ +0.2]	N/A	+0.2	+0.4	+0.4	0.0
High Rise (> 7 stories)	N/A	N/A	+0.6	+0.8	N/A	+0.8	+0.8	+0.6	+0.8	+0.3	N/A	+0.4	N/A	+0.6	N/A
Vertical Irregularity	-2.5	-2.0	-1.0	-1.5	N/A	-1.0	-1.0	-1.5	-1.0	[✓ -1.0]	N/A	-1.0	-1.0	-1.0	-1.0
Plan irregularity	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Pre-Code	0.0	-1.0	-1.0	-0.8	-0.6	-0.8	-0.2	-1.2	-1.0	-0.2	-0.8	-0.8	-1.0	-0.8	-0.2
Post-Benchmark	+2.4	+2.4	+1.4	+1.4	N/A	+1.6	N/A	+1.4	+2.4	N/A	+2.4	N/A	+2.8	+2.6	N/A
Soil Type C	0.0	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
Soil Type D	0.0	-0.8	-0.6	-0.6	-0.6	-0.6	-0.4	-0.6	-0.6	[✓ -0.4]	-0.6	-0.6	-0.6	-0.6	-0.6
Soil Type E	0.0	-0.8	-1.2	-1.2	-1.0	-1.2	-0.8	-1.2	-0.8	-0.8	-0.4	-1.2	-0.4	-0.6	-0.8
FINAL SCORE, S										20					

COMMENTS

Basic score para Mediana sismicidad para C3 es 3.2

Detailed Evaluation Required

[✓ YES] NO

* = Estimated, subjective, or unreliable data

DNK = Do Not Know

BR = Braced frame

FD = Flexible diaphragm

LM = Light metal

MRF = Moment-resisting frame

RC = Reinforced concrete

RD = Rigid diaphragm

SW = Shear wall

TU = Tilt up

URM INF = Unreinforced masonry infill

CONCLUSIONES

El edificio cuya vulnerabilidad estamos analizando, consta de dos edificaciones separadas por una junta de expansión. A estas edificaciones les hemos llamados Módulo A y Módulo B, siendo el Módulo A el edificio que está a la izquierda del observador colocado al frente del edificio, y el Módulo B el de la derecha. Ambos módulos están estructurado por pórticos de concreto en la dirección Norte - Sur y arriostrado en la dirección Este - Oeste. También consta de muros de mampostería como cerramiento laterales y en las divisiones internas. Este edifico fue construido en el año 1981, para tener un uso escolar. El estudio geotécnico y el de la refracción sísmica lo sitúan sobre un suelo firme a denso.

Característica del Módulo A

Este módulo contiene las escaleras, lo que le genera una irregularidad en planta. También se está produciendo un escalonamiento entre el área de distribución donde se encuentra la escaleras principales, produciéndole una irregularidad en elevación. En las columnas de las esquinas se están presentando cambios de rigidez, los pasamanos de los pasillos podrían generarle efectos de columnas cortas, al igual que los muros de mampostería en la zona de las ventanas.

Característica del Modulo B

Este módulo presenta regularidad en planta y el escenario del Auditorio le genera un escalonamiento lo que le provoca una irregularidad en elevación. También en el mismo se presentan los efectos de columna corta, en la zona del auditorio cambia de tres líneas de resistencia a dos, al igual que el Módulo A, las columnas de las esquinas presentan un cambio de rigidez.

Ambos módulos en el análisis de la vulnerabilidad, arrojaron valores de s=1.5 para el Módulo A y de s=2 para el Módulo B, por tanto hay que intervenir en dicha edificación.

BIBLIOGRAFÍAS

1. NEHRP Guidelines for the seismic rehabilitation of buildings (FEMA publication 273, 274), Washington, D,C., 1997.

2. Building Code Requirements for Structural Concrete, ACI-318-1999 y 2002.

3. Building Code Requirements for Mansory Structures, ACI-530-2002

4. Recomendaciones Provisionales para el Diseño Sísmico de Estructura, DNRS, MOPC, 1979.

5. Reglamento para Diseño y Construcción de Edificios en Mampostería Estructural, R- 027, DGRS,MOPC, 2007.

6. R. Park, T. Paulay,1980, Estructura de Concreto Reforzado, Editorial Limusa, México. 7- Enrique Bazan, Roberto Meli, 1999, Diseño Sísmico de Edificios, Editorial Limusa, México.

8. Ray W. Clough, Joseph Penzien, 1975, Dynamics of structures, Editorial MacGraw-hill, USA.

9. Efectos P-? en la Respuesta Sísmica No Lineal, Dr. Dionisio Bernal, MOPC, 1985.

10. Especificación, Diseño y Cálculo de Mampostería, Richard E. Klingner, TMS (The Mansori Society, Colorado, USA, 2005).

11. Seismic Evaluation and Retrofit of concrete Buildings, ATC-40 (Applied Technology Council), California, 1996.

12. Rapid Visual Screening of buildings for Potencial Seismic Hazards, FEMA 154, Edition 2 / March 2002.

13. Internegrafía

http://202.54.104.236/intranet/eha/Mitigacion/Contenidos/spanish/estructurales.htm

http://es.wikibooks.org/wiki/Patología_de_la_edificación/Estructuras_de_hormigón/Lesiones/Fisuración

http://books.google.com.do/books?id=gPsElo-1DIMC&printsec=frontcover#v=onepage&q=&f=false

Recibido: 10-12-2010
Aprobado: 10-01-2011