ASCE 41: Seismic Evaluation and Retrofit of Existing Buildings

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Intent – Provide basic understanding of Background, Applicability, and Process

- ASCE 41-17
- Items not covered – Design Examples & In-depth Analysis

**01** Brief History

**02** Applicability

**03** Tiered Process (Evaluation)

**04** Mitigation (Retrofit)
HISTORY
EXAMPLES OF EVENTS

- **1886 Charleston, SC**
  - Magnitude estimated 6.9-7.3
  - 60 Deaths and damaged 2,000 buildings
  - ~$5.5M in damages (~$150M in 2017)

- **1925 Santa Barbara, CA**
  - Magnitude estimated 6.5-6.8
  - 13 Deaths and Destroyed City Center
  - ~$8M in damages (~$111M in 2017)
HISTORY
EXAMPLES OF EVENTS

- 1933 Long Beach, CA
  - Magnitude estimated 6.4
  - 120 Deaths (mostly by falling debris)
  - ~$40M in damages (~$750M in 2017)

- 1971 San Fernando, CA
  - Magnitude estimated 6.5
  - 58 Deaths
  - ~$500M in damages (~$3B in 2017)
NEHRP, first authorized by Congress in 1977, coordinates the earthquake-related activities of the Federal Government.

GOAL: Mitigate earthquake losses in the U.S. through basic and directed research and implement activities in the fields of earthquake science and engineering

The four NEHRP federal agencies:

- FEMA – Federal Emergency Management Agency
- NIST – National Institute of Standards and Technology (LEAD Agency)
- NSF – National Science Foundation
- USGS – US Geological Survey
HISTORY

ATC 14 EVALUATING THE SEISMIC RESISTANCE OF EXISTING BUILDINGS

- Applied Technology Council (ATC) published one of the first set of *Guidelines for the Seismic Evaluation of Existing Buildings*, ATC-14 (1987)
  - First Attempt creating Seismic Evaluation Tool

  - Development of Checklists

- “Evaluation”
HISTORY
EXAMPLES OF EVENTS

- **1989 Loma Prieta, CA**
  - Magnitude estimated 6.9
  - 63 Deaths and nearly 4,000 Injuries
  - ~$12B in damages (in 2017 money)

- **1994 Northridge, CA**
  - Magnitude estimated 6.7
  - 57 Deaths and nearly 8,700 Injuries
  - Up to ~$70B (in 2017 money)
In the 1990’s, FEMA sought to update FEMA 178 methodology from recent events such as the 1989 Loma Prieta and the 1994 Northridge earthquakes (as well as from the development of performance based design procedures)


ASCE 31-03 – Seismic Evaluation of Existing Buildings

- Supersedes FEMA 310 Handbook
- Life Safety and Immediate Occupancy Performance Levels.
- Three-tier approach for screening buildings with checklist requirements for each tier.
  - Tier 1 - Screening Phase
  - Tier 2 - Evaluation Phase
  - Tier 3 - Detailed Evaluation.
- Includes evaluation procedures for geotechnical, foundation hazards, and nonstructural components in the building.
HISTORY
ASCE 41-06 SEISMIC REHABILITATION OF EXISTING BUILDINGS (2007)

- ASCE 41-06 – Seismic Rehabilitation of Existing Buildings
  - Supersedes FEMA 356 Handbook

- Expanded upon previous criteria

- Evaluation and Rehabilitation portions of the Codes have remained separate.
HISTORY

ASCE 41-13 SEISMIC EVALUATION AND RETROFIT OF EXISTING BUILDINGS (2014)

- ASCE 41-13 – Seismic **Evaluation** and **RETOFIT** of Existing Buildings
- First time Evaluation and Rehabilitation codes of Existing Buildings were combined.
- Three-tiered process for seismic evaluation
  - Tier 1 Screening
  - Tier 2 Deficiency-Based Evaluation and Retrofit
  - Tier 3 Systematic Evaluation and Retrofit
- Utilizes ASCE 7-10.
Updated from ASCE 41-13

Significant changes were included for the Basic Performance Objectives, seismic hazard used in Tier 1 and Tier 2, treatment of force-controlled components, nonlinear analysis provisions, nonstructural performance levels, demands on out-of-plane wall forces, modeling parameters and acceptance criteria of steel and concrete columns, and anchor testing.

Utilizes ASCE 7-16

Future code to be ASCE 41-23
APPLICABILITY

- American Society of Civil Engineers (ASCE) has no authority to enforce compliance
- Authority Having Jurisdiction (AHJ) shall determine requirements
Most know of the 50% PRV trigger for Anti-Terrorism (AT/FP) application; however, there are similar requirements for Seismic Evaluation and Retrofit triggers.

RP-8: *Standards of Seismic Safety for Existing Federally Owned and Leased Buildings* where “triggers” include:

- Building usage change that results on an Increase in Occupancy (Same as AT/FP)
- Renovations that significantly extends the building’s useful life
- As modified by UFC 3-310-04, Expenditure investment that totals more than:
  - 50% PRV for Building in SDC C
  - 30% PRV for Building in SDC D, E, or F
  - PRV – Plant Replacement Value
  - SDC – Seismic Design Category
- Buildings in SDC A or B are exempted based on RP-8, however, may still require evaluation based on the AHJ.
APPLICABILITY

FEDERAL SECTOR

- Building being repaired due to damage from fire, wind, earthquake, or other similar event to the buildings load bearing systems that require services of registered professionals
- AHJ designates the building to pose high risk to occupants or public
- Building added to the Federal Inventory through purchase or donation

- Documents such as P-100 (GSA) and the (DoD) reference the RP-8
- In turn, the RP-8 references ASCE 41
There's gonna be one...
NOW! No,... NOW!
Okay, maybee... NOW!
Alright, it's gonna be...
Now! Okayyy... Now!

Another long day down at the
Bureau of Earthquake Prediction
TIERED PROCESS

- **Screening**
  - Completion of checklists of evaluation statements that identify potential deficiencies in a building based on performance of similar buildings in past earthquakes

- **Evaluation**
  - An approach applicable to certain types of buildings and performance objectives based on specific evaluation of potential deficiencies to determine if they represent actual deficiencies that may require mitigation. Analysis of the response of the entire building may not be required.

- **Retrofit**
  - The mitigation of deficiencies identified in the Tier 1 Screening

- **Evaluation**
  - An approach to evaluation in which complete analysis of the response of the building to seismic hazards is performed, implicitly or explicitly recognizing non-linear response.

- **Retrofit**
  - An approach to retrofitting in which complete analysis of the response of the building to seismic hazards is performed, implicitly or explicitly recognizing nonlinear response.
Evaluation only utilized as the preliminary screening tool
- Intended to be “rapid” or “quick-checks”
- Series of pre-established checklists for evaluation of the buildings systems
  - Requiring some initial structural calculations
  - Designed to identify potential seismic deficiencies of the structural lateral-force resisting system(s) and nonstructural building systems
TIERS

- Upon completion of the Tier 1 process, any items found “Non-Compliant” or “Unknown” may begin the retrofit process or those items can be evaluated further to determine if they represent actual deficiencies that may require mitigation.
- Analysis shall conform to requirements of Chapter 7.
- Both evaluation and retrofit may require additional structural calculations and building modeling/analysis to address non-compliant Tier 1 items.
- Once the evaluation is completed, retrofit strategies are determined and implemented for seismic deficiencies in order to achieve an acceptable performance.
- Also, items deemed deficient by the engineer/evaluator based on analysis, experience, and engineering judgement will be included.
A Tier 3 Evaluation and Retrofit, if determined to be required based on the limitations and compliance requirements of ASCE 41 Tier 1 and Tier 2 results, is a systematic procedure involving the analysis of the entire building, typically placing all components with significant lateral stiffness in a mathematical model to ensure deformation capability under realistic seismic drifts.
Tier 1 and Tier 2 shall only be used with a Performance Objective that satisfies at least one of the following conditions:

- Seismic Hazard Level \( \leq \) BSE-1E with up to an Immediate Occupancy (1-B) Level
- i.e. Tiers 1 and 2 may not be used for Operational (1-A) Level
- BSE-1E < Seismic Hazard Level \( \leq \) BSE-2E with up to a Life Safety (3-C) Level

Tier 1 and Tier 2 procedures shall only be used for buildings conforming to Table 3-4.

Regardless of whether it is permitted for use, the Tier 1 Screening is a good starting point for the identification of potential deficiencies for any type listed in Common Building Type Table 3-1.

- Must Check Mixed Building Systems and System Combinations (Section 3.4.1.2)
- Tier 3 can be utilized as an option anytime and if Tier 1 and Tier 2 procedures are Not Permitted.
## Limitations on Tier 1 & 2 (Section 3.4.1 and Table 3-4)

### Table 3-4. Limitations on the Use of the Tier 1 and Tier 2 Procedures

<table>
<thead>
<tr>
<th>Common Building Type</th>
<th>Very Low</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wood Frames</strong></td>
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<tr>
<td>Light (W1)</td>
<td>NL</td>
<td>NL</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Multistory, multiunit residential (W1a)</td>
<td>NL</td>
<td>NL</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Commercial and industrial (W2)</td>
<td>NL</td>
<td>NL</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Steel Moment Frames</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Rigid diaphragm (S1)</td>
<td>NL</td>
<td>NL</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Flexible diaphragm (S1a)</td>
<td>NL</td>
<td>NL</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td><strong>Steel Braced Frames</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Rigid diaphragm (S2)</td>
<td>NL</td>
<td>NL</td>
<td>8</td>
<td>8</td>
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<tr>
<td>Flexible diaphragm (S2a)</td>
<td>NL</td>
<td>NL</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td><strong>Unreinforced Masonry Bearing Walls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexible diaphragm (URM)</td>
<td>NL</td>
<td>NL</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Rigid diaphragm (URMa)</td>
<td>NL</td>
<td>NL</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td><strong>Seismic Isolation or Passive Dissipation</strong></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>NP&lt;sup&gt;a&lt;/sup&gt;</td>
<td>NP&lt;sup&gt;a&lt;/sup&gt;</td>
<td>NP&lt;sup&gt;a&lt;/sup&gt;</td>
<td>NP&lt;sup&gt;a&lt;/sup&gt;</td>
<td>NP&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

### Notes:
- The Tier 3 systematic procedures are required for buildings with more than the number of stories listed herein.
- Common building types are defined in Section 3.2.1.
- Number of stories shall be considered as the number of stories above lowest adjacent grade.
- NL = No Limit (No limit on the number of stories).
- NP = Not Permitted (Tier 3 systematic procedures are required).
- No deficiency-based procedures exist for these building types. If they do not meet the Benchmark Building requirements, Tier 3 systematic procedures are required.
TIER 1 PROCESS

Tier 1 Screening (Figure 4-1)

- ESTABLISH a Performance Objective & Performance Levels
- DETERMINE Level of Seismicity
- IDENTIFY Common Building Types
- CHECK Benchmark Building
- SELECT Checklists (Basic, Structural, Non-Structural)
- ASSESS Findings to Determine Deficiencies and a Path Forward

Figure 4-1. Tier 1 Evaluation Process
Note: IO = Immediate Occupancy, LS = Life Safety.
### TIER 1 PROCESS

**ESTABLISH Performance Objective and Performance Levels**

- **Building Performance Level (Alpha-Numeric) = Structural + Non-Structural**

#### Nonstructural Performance Level

<table>
<thead>
<tr>
<th>N-A</th>
<th>Operational</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-B</td>
<td>Position Retention</td>
</tr>
<tr>
<td>N-C</td>
<td>Life Safety (LS)</td>
</tr>
<tr>
<td>N-D</td>
<td>Hazards Reduced</td>
</tr>
<tr>
<td>N-E</td>
<td>Not Considered</td>
</tr>
</tbody>
</table>

#### Structural Performance Level

<table>
<thead>
<tr>
<th>S-1</th>
<th>Immediate Occupancy (IO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-2</td>
<td>Damage Control</td>
</tr>
<tr>
<td>S-3</td>
<td>Life Safety (LS)</td>
</tr>
<tr>
<td>S-4</td>
<td>Limited Safety</td>
</tr>
<tr>
<td>S-5</td>
<td>Collapse Prevention (CP)</td>
</tr>
<tr>
<td>S-6</td>
<td>Not Considered</td>
</tr>
</tbody>
</table>

#### Nonstructural Performance Levels

<table>
<thead>
<tr>
<th>Operational</th>
<th>Position Retention</th>
<th>Life Safety</th>
<th>Hazards Reduced</th>
<th>Not Considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-A</td>
<td>N-B</td>
<td>N-C</td>
<td>N-D</td>
<td>N-E</td>
</tr>
</tbody>
</table>

#### Structural Performance Levels

<table>
<thead>
<tr>
<th>Immediate Occupancy (IO)</th>
<th>Damage Control</th>
<th>Life Safety (LS)</th>
<th>Limited Safety</th>
<th>Collapse Prevention (CP)</th>
<th>Not Considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>S-1</td>
<td>2-A</td>
<td>Not Recommended</td>
<td>Not Recommended</td>
<td>Not Recommended</td>
<td>Not Recommended</td>
</tr>
<tr>
<td>S-2</td>
<td>Immediate Occupancy (1-B)</td>
<td>3-B</td>
<td>4-B</td>
<td>Not Recommended</td>
<td>Not Recommended</td>
</tr>
<tr>
<td>S-3</td>
<td>2-C</td>
<td>Life Safety (3-C)</td>
<td>5-C</td>
<td>6-C</td>
<td>6-D</td>
</tr>
<tr>
<td>S-4</td>
<td>Not Recommended</td>
<td>Not Recommended</td>
<td>3-D</td>
<td>4-D</td>
<td>5-E</td>
</tr>
<tr>
<td>S-5</td>
<td>Not Recommended</td>
<td>Not Recommended</td>
<td>3-E</td>
<td>4-E</td>
<td>5-E</td>
</tr>
<tr>
<td>S-6</td>
<td>Not Recommended</td>
<td>Not Recommended</td>
<td>3-F</td>
<td>4-F</td>
<td>5-F</td>
</tr>
</tbody>
</table>

*Note: (Building Performance Level = Structural Performance Level + Nonstructural Performance Level)*
Seismic Hazard (Basic Safety Earthquake [BSE])

- BSE–2N: BSE-2 for use with Basic Performance Objective Equivalent to New Building Standards, taken as the ground shaking based on the Risk-Targeted Maximum Considered Earthquake (MCE_R) per section 11.4 of ASCE 7, at a site. \( S_{xs} = S_{ms} = F_a S_s \) and \( S_{x1} = S_{m1} = F_v S_1 \)
  - 2% probability of exceedance in 50 years

- BSE–2E: BSE-2 for use with Basic Performance Objective for Existing Building, taken as a seismic hazard with a 5% probability of exceedance in 50 years, but not greater than BSE-2N, at a site.

- BSE–1N: BSE-1 for use with Basic Performance Objective Equivalent to New Building Standards taken as \textit{two-thirds} of BSE-2N, at a site. \( S_{ds} = 2/3 S_{ms} \) and \( S_{d1} = 2/3 S_{d1} \)
  - Previously considered 10% probability of exceedance in 50 years but no longer referenced

- BSE–1E: BSE-1 for use with Basic Performance Objective for Existing Building, taken as a seismic hazard with a 20% probability of exceedance in 50 years, but not greater than BSE-1N, at a site
**TIER 1 PROCESS**

**ESTABLISH** Performance Objective and Performance Levels

### Site in Tennessee

<table>
<thead>
<tr>
<th></th>
<th>SITE CLASS C</th>
<th>SITE CLASS D</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSE-2N</td>
<td>BSE-1N</td>
<td>BSE-2E</td>
</tr>
<tr>
<td>$S_s$</td>
<td>0.517</td>
<td>0.326</td>
</tr>
<tr>
<td>$S_1$</td>
<td>0.123</td>
<td>0.084</td>
</tr>
<tr>
<td>$S_{xs}$</td>
<td>0.669</td>
<td>0.446</td>
</tr>
<tr>
<td>$S_{x1}$</td>
<td>0.18</td>
<td>0.123</td>
</tr>
</tbody>
</table>

### Site in California

<table>
<thead>
<tr>
<th></th>
<th>SITE CLASS C</th>
<th>SITE CLASS D</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSE-2N</td>
<td>BSE-1N</td>
<td>BSE-2E</td>
</tr>
<tr>
<td>$S_s$</td>
<td>1.974</td>
<td>1.508</td>
</tr>
<tr>
<td>$S_1$</td>
<td>0.703</td>
<td>0.522</td>
</tr>
<tr>
<td>$S_{xs}$</td>
<td>2.369</td>
<td>1.579</td>
</tr>
<tr>
<td>$S_{x1}$</td>
<td>0.985</td>
<td>0.657</td>
</tr>
</tbody>
</table>

- **Seismic Hazard**
  - Site Specific
  - Soil Specific
  - Based on Contour Maps
  - [https://seismicmaps.org/](https://seismicmaps.org/)
  - ASCE 41-17
**Basic Performance Objective (BPO) = Seismic Hazard Level + Performance Level**

- **Operational (1-A)**: Minimal to no damage and occupancy, operations, and functions suitable immediately.
- **Immediate Occupancy (1-B)**: Minimal to no damage and occupancy suitable immediately. Operations/functions interrupted and may need some repair.
- **Life Safety (3-C)**: Some non-life-threatening injuries possible. Components damaged and repair may be required prior to re-occupancy.
- **Collapse Prevention (5-D)**: Building remains standing but only barely to evacuate immediately. Demolition anticipated post event.

### Performance Objective for Existing Buildings (BPOE)

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>BSE-1E</th>
<th>BSE-2E</th>
<th>BSE-1E</th>
<th>BSE-2E</th>
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<tbody>
<tr>
<td>I &amp; II</td>
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<tr>
<td>Structural Performance Not Evaluated</td>
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<tr>
<td>Life Safety Nonstructural Performance (3-C)</td>
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<tr>
<td>Collaps Prevention Structural Performance Hazards Reduced Nonstructural Performance (5-D)</td>
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<tr>
<td>II</td>
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<td>Structural Performance Not Evaluated</td>
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<tr>
<td>Position Retention Nonstructural Performance (2-B)</td>
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<tr>
<td>Limited Safety Structural Performance Hazards Reduced Nonstructural Performance (4-D)</td>
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<tr>
<td>III</td>
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<tr>
<td>Structural Performance Not Evaluated</td>
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<tr>
<td>Position Retention Nonstructural Performance (1-B)</td>
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<tr>
<td>Immediate Occupancy Structural Performance Hazards Reduced Nonstructural Performance (3-D)</td>
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<tr>
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<tr>
<td>Immediate Occupancy Structural Performance Hazards Reduced Nonstructural Performance (1-B)</td>
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<tr>
<td>BPON (Basic Performance Objective Equivalent to New Building Standards)</td>
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<tr>
<td>- Varies with Risk category</td>
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<tr>
<td>BPON (Basic Performance Objective Equivalent to New Building Standards)</td>
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<tr>
<td>- Varies with Risk category</td>
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<tr>
<td>BPON (Basic Performance Objective Equivalent to New Building Standards)</td>
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<tr>
<td>- Use only with Tier 3</td>
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</tbody>
</table>
TIER 1 PROCESS
DETERMINE Level of Seismicity

- Very low: $S_{DS} < 0.167g$, $S_{D1} < 0.067g$
- Low: $0.167g < S_{DS} < 0.33g$, $0.067g < S_{D1} < 0.133g$
- Moderate: $0.33g < S_{DS} < 0.50g$, $0.133g < S_{D1} < 0.20g$
- High: $S_{DS} > 0.50g$, $S_{D1} > 0.20g$
The building shall be classified as one or more of the common building types listed in Table 3-1 based on the seismic-force-resisting system and the diaphragm type. If the structural system is not one or more of those described in Table 3-1, then Tiers 1 and 2 shall not be permitted for evaluation or deficiency-based retrofit.

| Concrete Shear Walls C2 (with Stiff Diaphragms) | These buildings have floor and roof framing that consists of cast-in-place concrete slabs, concrete beams, one-way joists, two-way waffle joists, or flat slabs. Buildings may also have steel beams, steel columns, cold-formed steel light-frame construction, and concrete slabs for the gravity framing. Floors are supported on concrete columns or bearing walls. Seismic forces are resisted by cast-in-place concrete shear walls. In older construction, shear walls are lightly reinforced but often extend throughout the building. In more recent construction, shear walls occur in isolated locations, are more heavily reinforced, and have concrete slabs that are stiff relative to the walls. The foundation system is permitted to consist of a variety of elements. |
| C2a (with Flexible Diaphragms) | These buildings are similar to C2 buildings, except that diaphragms consist of wood sheathing, or have large aspect ratios, and are flexible relative to the walls. |
TIER 1 PROCESS
CHECK Benchmark Buildings (Table 3-2)

- A building designed and constructed or evaluated to a specific Performance Level using an acceptable code or standard listed in Table 3-2 (Life Safety Structural Performance) and Table 3-3 (Immediate Occupancy Structural Performance) Basic Performance Objective (BPO)

- Buildings that have been fully retrofitted shall be evaluated using the standards used for the retrofit, not the original design provisions.

Example

- i. Building Built in 1960’s with Cast-in-place concrete (Type C1 and C2) and Precast concrete (Type PC2) construction types
- ii. Retrofitted in 1990’s (per 1991 NEHRP)
- iii. Per Table 3-2, not qualified as Benchmark Building
- iv. Additionally, the newest changes to the controlling structural loads criteria (ASCE 7-16; Minimum Design Loads and Associated Criteria for Buildings and Other Structures) has impacts to this site. In this update, the seismic parameters of the area were increased from previous standards.
TIER 1 PROCESS
SELECT Checklists (CHAPTER 17)

- Checklist for EACH building type
- (Function of Level of Seismicity and Performance Level:
  - Compliant (C), Noncompliant (NC), Not Applicable (N/A), or Unknown (U).

- Basic Checklists
  - Very Low Seismic Checklist
  - Basic Configuration Checklist
    - Collapse Prevention
    - Immediate Occupancy

- Structural System(s) Checklists
  - Building systems and configurations

- Nonstructural Checklists
  - Ceilings, Equipment, Furnishings, Hazardous materials, cladding, partition walls, elevators, etc. (Failing Items that can cause hazards to building occupants)
  - LMH - Seismicity: Low, Moderate, and High
  - HR - Hazards Reduced
  - LS – Life Safety
  - PR – Position Retention
TIER 1 PROCESS
ASSESS Findings to Determine Deficiencies and a Path Forward

- Where the potential deficiencies were identified in the Tier 1 Screening, a Tier 2 or 3 Deficiency-based Evaluation and Retrofit may be performed.

- Only the potential deficiencies identified by the noncompliant checklists statements need to be assessed.

- Construction documents, including drawings, specifications, and a quality assurance plan, may be developed.
MITIGATION (RETROFIT)

Chapter 7 – Analysis Procedures
- Linear Static Procedure (LSP)
- Linear Dynamic Procedure (LDP)
- Non-linear Static Procedure (NSP)
- Non-linear Dynamic Procedure (NDP)
- Force or Deformation Controlled Actions

Chapter 8 – Foundations / Geotechnical

Chapter 9 – Steel and Iron

Chapter 10 – Concrete

Chapter 11 – Masonry

Chapter 12 - Wood

Chapter 13 – Architectural and MEP Components
- Permanent or Integral parts of the building
- Non-Structural

Chapter 14 – Seismic Isolation

Chapter 15 – Supplement Energy Dissipation

Chapter 16 – System-Specific

Chapter 17 – Tier 1 Checklists

Appendices and Commentary
MITIGATION (RETROFIT)

- Steel (Numerous Possibilities)
  - Braces
  - Connections
  - Plating
  - Increase Section Properties
  - Anchorage
MITIGATION (RETROFIT)

- Steel (Numerous Possibilities)
MITIGATION (RETROFIT)

- Steel (Numerous Possibilities)
MITIGATION (RETROFIT)

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Masonry

“Slice and Dice” – Post installed Rebar into existing CMU

Partition Walls

Steel Bracing

Light Gauge Studs

FRP

Steel Ties (i.e. Heli-Tie)
MITIGATION (RETROFIT)

- Fiber Reinforced Polymer (FRP)
  - Good for Masonry and Concrete
  - Column Rebar Confinement
  - Shear and Flexural Capacity
  - Beam-Column Joint Reinforcement
MITIGATION (RETROFIT)

- Fabric Reinforced Cementitious Matrix (FRCM)

```plaintext
<table>
<thead>
<tr>
<th>Traditional Shotcrete Repair</th>
<th>FRCM Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before FRCM</td>
<td>After FRCM</td>
</tr>
</tbody>
</table>
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Diagram:
- Cementitious matrix
- Fabric
- Fabric/matrix interface
- FRCM/substrate interface

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QUESTIONS?

James Bond slept through an earthquake.
He was shaken but not stirred.