ASCE 41-13 Hands-On Approach

ASCE 41-13 Performance-Based Design and General Provisions

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*The view expressed represent those of the author, not the standard’s committee as a whole.

Evolution of Earthquake Design Standards

- “You see certain clues in '64 (Alaska Earthquake) that make you raise questions, and you see a lot more in '67 (Caracas Earthquake). Then all of a sudden you start questioning things.”

- “The basic coefficients we got into codes were not derived from a theoretical point of view, but were based on observations of earthquake damage to actual buildings.”

- Henry Degenkolb (EERI Oral History)

Learning From Earthquakes

Photo courtesy of Degenkolb Engineers
1971 San Fernando Earthquake

Concrete Construction
1960's concrete reinforcing requirements did not provide good behavior due to lack of confinement.

Tilt-up Concrete
Connection of wall to roof identified as deficient.
Steel Braced Frame Issues

Precast Concrete Issues

New Building vs. Existing Building Standards
1976 UBC and Previous

Deliberate omission of “return period”
Provide minimum design force of around 10% for “ductile” moment frame
Engineers in SF felt that new forces in ’76 UBC would mean that all existing building would be considered unsafe
Practice began to check existing buildings for 75% of new building forces

ATC 3

Provide equal probability throughout the country of design ground motion being exceeded
If ground motion occurred “… there might be life threatening damage in 1 to 2 percent of buildings…”
Section specifically for existing buildings
Effectively 50% of “New Code” OK for evaluation
Recommend 100% of “New Code” for retrofit

ATC 14

Checklist for typical deficiencies in common buildings
Deficiency-only evaluation procedure
Hazard based on 75% of most recent UBC
Allowable stress based checks
Effectively 75% of “New Code” for evaluation
Updated to be FEMA 178 and continued this trend
Performance-based seismic retrofit guideline
User chose the earthquake hazard level to evaluate
User chose the building performance level
Provided a “Basic Safety Objective” which was similar to a new building
Systematic evaluation and retrofit of the building
Evolved to FEMA 356 and then to ASCE 41

FEMA 273 / FEMA 356 / ASCE 41-06

Recalibrate ATC 14/FEMA 178 to FEMA 273 performance-based provisions
Hazard based on 2/3*MCE
Same hazard as new code design
Acceptance criteria based on FEMA 273, but calibrated to be approximately 4/3 higher (1/0.75)
Allow passing the evaluation at less than (75%) new building

FEMA 310 / ASCE 31

Four seismic hazards defined, but any can be chosen
Provides a method to match new design standard performance objective (BPON)
Provides a method similar to the historically accepted lower performance objectives for existing buildings (BPOE)

ASCE 41-13

Combines ASCE 31-03 checklist and deficiency-only method with ASCE 41-06 systematic method
Four seismic hazards defined, but any can be chosen
Provides a method to match new design standard performance objective (BPON)
Provides a method similar to the historically accepted lower performance objectives for existing buildings (BPOE)
Why not use new building standards?
- New building standards assume conformance of all elements.
- Existing buildings often have a mix of conforming and non-conforming elements.
- What is the right R-factor for an existing building?
- Deformation compatibility requirements in new design rely on conforming details.

Why use an existing building specific standard?
- ASCE 41 is focused on elements as opposed to systems.
- ASCE 41 has more explicit protections for “weak links.”
- ASCE 41 has more explicit deformation compatibility requirements.
New building standards may discount existing elements.

**ASCE 41-13**

Performance-based standard
Deficiency-based and systematic procedures
Capacity-based design philosophy
Displacement-based analysis provisions

**Tier 1**

**Performance Objectives**

**Procedure Limitations**

**Tier 2**

**Tier 3**
Deficiency-based vs. Systematic

Systematic = Evaluate Everything

Deficiency-based = Evaluate the specific deficiencies

Deficiency-based vs. Systematic

ASCE 41 Tier 1 & Tier 2 = Deficiency-based

ASCE 41 Tier 3 = Systematic
What is a Systematic Procedure?
- Evaluate everything
- Computationally intensive
- No assumptions about adequacy without analytical justification

What is a Deficiency-based procedure?
- Based on past earthquake observations
- Identify potential deficiencies based on:
  - Structural configuration
  - Construction material
  - Era of building, and
  - Structural system
- Calculations only required for the potential deficiencies
- Other items may be analytically noncompliant, but ignored
- Limitations on use in Tier 1 and Tier 2

Performance-Based Earthquake Engineering

Safe

Unsafe

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Earthquake Performance Levels

- Immediate Occupancy
- Damage Control
- Life Safety
- Limited Safety
- Collapse Prevention

ASCE 41-13 Structural Performance Levels

- Enhanced Safety
- Reduced Safety

Immediate Occupancy
New Design Equivalent Hazards – No "Break"

- **BSE-2N** is the ASCE 7-10 MCE (varies from 5% to 1% in 50-year, typically 2%)
- **BSE-1N** is 2/3 ASCE 7-10 MCE (varies from 20% to 10% in 50-year, typically 10%)

Existing Building Hazards – the "Break"

- **BSE-2E (C)** is the 5% in 50-year (975-year)
- **BSE-1E (R)** is the 20% in 50-year (225-year)

**BSE-2E and BSE-1E cannot be greater than the BSE-2N and BSE-1N**

- In SF, San Jose, parts of LA, and Oakland this means no force reduction for existing buildings
Performance Objective

= Seismic Hazard Level + Structural, Nonstructural, or Building Performance Level

Building Performance Level

= Structural Performance Level + Nonstructural Performance Level

<table>
<thead>
<tr>
<th>Building Performance Levels</th>
<th>Immediate Occupancy</th>
<th>Damage Control</th>
<th>Life Safety</th>
<th>Limited Safety</th>
<th>Collapse Prevention</th>
<th>Structural and Considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational Operational</td>
<td>Uncommon</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Position Retention</td>
<td>Common</td>
<td>Common</td>
<td>Uncommon</td>
<td>NR</td>
<td>NR</td>
<td>NR</td>
</tr>
<tr>
<td>Hazards Reduced*</td>
<td>Uncommon</td>
<td>Uncommon</td>
<td>Common</td>
<td>Collapse</td>
<td>Prevention*</td>
<td>Common</td>
</tr>
<tr>
<td>Nonstructural Not Considered</td>
<td>NR</td>
<td>NR</td>
<td>Common</td>
<td>Common</td>
<td>Do-nothing</td>
<td></td>
</tr>
</tbody>
</table>

NR = Not recommended due to disparity between structural and nonstructural levels
Operational
Immediate
Occupancy
Life Safety
Collapse Prevention

Earthquake Hazard Level

Building Performance Level

BPON Risk Category II = ASCE 41-06 Basic Safety Objective
- Check Structural Life Safety at the BSE-1N
- Check Structural Collapse Prevention at the BSE-2N
- Check Nonstructural Position Retention at BSE-1N

Basic Performance Objective Equivalent to New Building Standards (BPON)

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>BSE-1N Life Safety Performance</th>
<th>BSE-2N Collapse Prevention Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>I &amp; II Typical buildings</td>
<td>Structural Performance</td>
<td>Structural Performance</td>
</tr>
<tr>
<td>III Schools, Assembly</td>
<td>Damage Control Structural Performance</td>
<td>Limited Safety Structural Performance</td>
</tr>
<tr>
<td>IV Essential facilities (i.e. hospitals &amp; EOCs)</td>
<td>Immediate Occupancy Structural Performance</td>
<td>Life Safety Structural Performance</td>
</tr>
<tr>
<td></td>
<td>Operational Nonstructural Performance</td>
<td>Nonstructural Performance Not Considered</td>
</tr>
</tbody>
</table>

Why check both the Design Earthquake (BSE-1N) and the MCER (BSE-2N) when ASCE 7 only requires one?

BPON Risk Category II

Roof Displacement

Force

Displacement @ 2/3*MCER

Displacement @ MCE_r

Building EQ response if code compliant

Building EQ response

Strength of W*Sa,2/3*MCER / R

BPOE Risk Category

BSE-1E

BSE-2E

Life Safety Structural Performance

Life Safety Nonstructural Performance

Prevention Structural Performance

Prevention Nonstructural Performance Not Considered

II (Schools, Assembly)

Damage Control Structural Performance

Position Retention Nonstructural Performance

Immediate Occupancy Structural Performance

Immediate Occupancy Nonstructural Performance Not Considered

IV (Essential facilities, i.e. hospitals & EOCs)

Life Safety Structural Performance

Life Safety Nonstructural Performance Not Considered

BPOE = ASCE 31-03 Life Safety & Immediate Occupancy

BPOE represent a lesser performance objective that has historically been accepted for existing buildings.

- "E" hazards used instead of "N" hazards as opposed to ¾ "code" or higher "m"
- Same structural performance levels
- Nonstructural is Life Safety instead of Position Retention for RC I & II
- Nonstructural is Position Retention instead of Operational for RC IV
- In Tier 1 & Tier 2, only need to check performance in the BSE-1E

*In ASCE 41-17 T1 & T2 structural checks will be done at BSE-2E.
San Francisco Example

New Design Equivalent Hazards – No “Break”

BSE-2N is 1.50
BSE-1N is 1.00

Existing Building Hazards – the “Break”

BSE-2E is 1.48 (99% of MCE)
BSE-1E is 0.99 (99% of 2/3*MCE)
BSE-2E/BSE-1E = 1.5

41-13 to 31-03 – 33% increase in demand due to BSE-1E and BSE-1N the same.
41-17 to 31-03 – 50% increase in demand due to BSE-2E and BSE-2N the same.

Los Angeles Example

New Design Equivalent Hazards – No “Break”

BSE-2N is 2.40
BSE-1N is 1.60

Existing Building Hazards – the “Break”

BSE-2E is 1.76 (73% of MCE)
BSE-1E is 0.84 (53% of 2/3*MCE)
BSE-2E/BSE-1E = 2.0

41-13 to 31-03 – ASCE 31 2/3MCE = 1.44 is 77% of ASCE 31 demand.
41-17 to 31-03 – 22% increase from ASCE 31-03 demand.

Salt Lake City Example

New Design Equivalent Hazards – No “Break”

BSE-2N is 1.54
BSE-1N is 1.03

Existing Building Hazards – the “Break”

BSE-2E is 1.07 (69% of MCE)
BSE-1E is 0.29 (28% of 2/3*MCE)
BSE-2E/BSE-1E = 3.7

41-13 to 31-03: 2/3MCE = 1.15, 41-13 is 34% of ASCE 31 demand.
41-17 to 31-03: 2/3MCE = 1.15, 41-17 is 93% of ASCE 31 demand.
New Design Equivalent Hazards – No “Break”

- BSE-2N is 1.01
- BSE-1N is 0.67

Existing Building Hazards – the “Break”

- BSE-2E is 0.71 (67% of MCE)
- BSE-1E is 0.13 (19% of MCE)

41-13 to 31-03: 2/3MCE = 0.93, 41-13 is 19% of ASCE 31 demand
41-17 to 31-03: 2/3MCE = 1.15, 41-17 is 62% of ASCE 31 demand

Memphis Example

Any combination that results in one or both of the performance objectives given in the BPOE table being exceeded.

For example:
- Using provisions for a higher risk category than required.
- Using a higher seismic hazard than the BSE-1E for checking Life Safety.
- Targeting IO at the BSE-1E but only CP at the BSE-2E for an RC II building.
- The BPON is technically an enhanced performance objective.

Enhanced Performance Objective

Limited Performance Objective

Limited performance objectives or partial retrofits are permitted provided:

1. The current performance levels of the structural and nonstructural systems are not reduced
2. A new irregularity is not created, nor an existing one made more severe
3. Seismic forces in deficient components are not increased
4. All new elements comply with provisions in ASCE 41
### Reduced Performance Objective

Any combination that results in lower the performance objectives than those given in the BPOE table.

For example:
- Only checking structural Life Safety in the BSE-1E
- Permitting Collapse Prevention in the BSE-2E instead of Life Safety for a RC IV structure
- Using a seismic hazard lower than the BSE-1E

### Partial Retrofit Objective

A partial retrofit is deemed a limited performance objective.

For example:
- Only addressing most severe deficiencies
- Retrofitting one portion of a structure
- Completing the first phase a multi-step project