PERFORMANCE OF A NONDUCTILE RC BUILDING FOR THE FEMA P695 FAR-FAULT GROUND MOTION DATA SET

Adolfo B. Matamoros, Anil Suwal, and Andres Lepage
### ASCE-41 Standard

#### Modeling Parameters

![Graph showing deformation ratio](image)

#### Rehabilitation Objective

<table>
<thead>
<tr>
<th>Earthquake Hazard Level</th>
<th>Target Building Performance Levels</th>
<th>Operational Performance Level (1-A)</th>
<th>Immediate Occupancy Performance Level (1-B)</th>
<th>Life Safety Performance Level (3-C)</th>
<th>Collapse Prevention Performance Level (6-E)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50%/50 year</td>
<td>72 yrs</td>
<td>a</td>
<td>b</td>
<td>c</td>
<td>d</td>
</tr>
<tr>
<td>20%/50 year</td>
<td>225 yrs</td>
<td>e</td>
<td>f</td>
<td>g</td>
<td>h</td>
</tr>
<tr>
<td>BSE-1</td>
<td>474 yrs (≈10%/50 year)</td>
<td>i</td>
<td>j</td>
<td>k</td>
<td>l</td>
</tr>
<tr>
<td>BSE-2</td>
<td>2475 yrs (≈2%/50 year)</td>
<td>m</td>
<td>n</td>
<td>o</td>
<td>p</td>
</tr>
</tbody>
</table>

#### Acceptance Criteria

![Graph showing deformation or deformation ratio](image)

(c) Component or element deformation acceptance criteria

Maximum Considered Earthquake

1/3/11
FEMA P695 Methodology

Equivalent safety against collapse for buildings with different seismic force resisting systems

Collapse Safety Margin \( \rightarrow \) Design Criteria for Building Codes (i.e. \( R, C_d \), and \( \Omega_0 \) seismic performance factors)

Median Collapse: One-half of the structures have some form of collapse

Local Instability \( \rightarrow \) Global Instability

 Collapse Margin Ratio, \( CMR = \) \( \frac{SA \text{ Median collapse-level ground motions}}{SA \text{ of } MCE \text{ ground motions}} \)

NEHRP: Structure should have a low probability of collapse for \( MCE \) (1.5 times the design level earthquake)
Building Description

- Seven-story RC Building in Van Nuys, CA
- Designed in 1965 and constructed in 1966
- Exterior moment-resisting frames
- Interior gravity load flat slab system
- Strong motion records from:
  - 1971 San Fernando
  - 1987 Whittier
  - 1990 Upland
  - 1992 Sierra Madre
  - 1994 Northridge
- Light structural damage during the 1971 San Fernando Earthquake, severe column damage during the 1995 Northridge earthquake.
Building Plan

35 x 50 cm ext. columns

40 x 56 cm spandrel beam around perimeter (40 x 75 cm first floor)

45 cm square int. columns

19.1 m

45.7 m

interior frame

exterior frame
Lumped Plasticity Model for Frame Structure

Moment rotation relationship for nonlinear rotational spring of second story column of RC Building
Collapse Simulation
CMR is established through Incremental Dynamic Analysis

Ground motion set scaled to MCE

Ground motion records

Interstory Drift Ratio

Mean Drift Ratio

Base Acceleration

Deformed Shape

Response [g]

Natural Period [s]

Height (in.)

Time (sec)

Mean Drift Ratio

Interstory Drift Ratio

Baseline Shape

MCE

Average

Ground motion records

1st Story
2nd story
3rd story
4th story
5th story
6th story
7th story
Average
Collapse Simulation Results EW Direction

![Diagram showing moment vs. rotation for ASCE 41-13 and ACI 369 columns.](image)

- **Moment vs. Rotation**: The graph illustrates the relationship between moment (kip in.) and rotation (radians) for both ASCE 41-13 and ACI 369 columns.

- **Probability of Collapse-Lateral Instability**: The graph shows the probability of collapse-lateral instability for different intensity measures (IM).

- **Intensity Measure (IM)**: The x-axis represents the intensity measure, ranging from 0.0 to 2.5.

- **50% PE**: The graph indicates the 50% probability of exceedance (PE) for each model.

- **Northridge**: The graph highlights the Northridge event with corresponding IM values.
Two Node Joint Elastic Element Joint Offset

ASCE 41-13

ASCE 41-17

Probability of Exceeding Column Modeling Parameters

Northridge

50% PE

Yield

Capping

Post-Capping

Probability of Exceeding MP

Intensity Measure

Northridge

50% PE

Yield

Capping

Post-Capping

Probability of Exceeding MP

Intensity Measure
Probability of Exceeding Column Acceptance Criteria

ASCE 41-13

ASCE 41-17
Conclusions

• Due to the lack of ductile detailing, the case-study building will reach local collapse at much lower earthquake intensities (50% at IM 0.65) than would cause dynamic instabilities (50% at IM 0.85).

• Comparison of fragility relationships based on ASCE 41-13 and -17 standards show that acceptance criteria for IO were similar, and the changes in acceptance criteria were noticeable for the LS and CP limit states.

• The greater gap between the curves corresponding to LS and CP observed for the ACI 369 acceptance criteria is a better representation of performance objectives defined in Chapter 2 of ASCE 41 where, for example, the Enhanced Objective corresponds both to seismic hazard level BSE-1 (10% probability of exceedance in 50 yrs) with performance level LS and seismic hazard level BSE-2 (2% probability of exceedance in 50 years) with performance objective CP.

• The performance level of the case study building was controlled by the exterior beams, which are the elements of least concern to the gravity load system. The effect of element damage on the probability of collapse should be considered when formulating Acceptance Criteria.
Acknowledgments

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