FEMA P-58-7

Building the Performance You Need

State-of-the-Art Tools for Seismic Design & Assessment
FEMA P-58-7: Building the Performance You Need

Structure
25% of building value

75% of building value
PACT: Performance Assessment Calculation Tool
Next Generation Assessment Process

- Probable consequences and explicit consideration of uncertainty
  - Casualties
  - Repair costs
  - Repair time
  - Unsafe placarding
  - Environmental Impacts
OPTIONS FOR EARTHQUAKE RESISTANT DESIGN
Design Decisions Have Measurable Consequences

Consequences Under Major Earthquake

<table>
<thead>
<tr>
<th>Casualty Risks</th>
<th>Chance of Post-EQ Placard</th>
<th>Expected Building Downtime</th>
<th>Initial Building Cost</th>
<th>Repair Cost</th>
<th>Carbon Impacts of Repairs</th>
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</tbody>
</table>

Moderate EQ: 2% chance in 50 years
Major EQ: 10% chance in 50 years
Extreme EQ: 2% chance in 50 years

New Buildings
- Protective System
- Enhanced Code*
- Basic Code
- Basic Retrofit**
- Unretrofitted

Older Buildings

bigger EQs

FEMA P-58-7: Building the Performance You Need
OPTIONS FOR EARTHQUAKE RESISTANT DESIGN
Design Decisions Have Measurable Consequences

Consequences Under Major Earthquake

Casualty Risks | Chance of Post-EQ Placard | Expected Building Downtime | Initial Building Cost | Repair Cost | Carbon Impacts of Repairs
---|---|---|---|---|---

New Buildings

- Moderate EQ
  - 2% chance in 50 years
- Major EQ
  - 10% chance in 50 years
- Extreme EQ
  - 2% chance in 50 years

Enhanced Code*

Basic Code

Basic Retrofit**

Older Buildings

- Unretrofitted

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New Buildings

- Protective System
- Enhanced Code
- Basic Code

Older Buildings

- Basic Retrofit
- Unretrofitted

FEMA P-58-7: Building the Performance You Need
PACT: Performance Assessment Calculation Tool

Next Generation Assessment Process

Ground Motion

Structural Response

Damage

Fragility Spec

Building Performance Model

Consequences

FEMA P-58-7: Building the Performance You Need
Code Performance
Ductility is Damage
Design Space Approach
Defines parametric limits based on practical designs
Generic design space and representative

[Diagram showing a grid with points labeled as Stiffest/strongest considered design, Maximum drift, high lateral strength, Maximum stiffness, minimum lateral strength, Code minimum design, max. drift/min. strength, and Design Story Drift Ratio.]

FEMA P-58-7: Building the Performance You Need
FEMA P-58 Performance Results

- Repair costs (% rep.)
FEMA P-58 Performance Results

- Repair times (days)
## Expected Code Performance

### Table 6-1: Generalized Performance Expectations for Code-Conforming Buildings

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Performance Expectation</th>
<th>Design EQ</th>
<th>MCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Risk Category IV – Office (Emergency Operations Center)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repair Cost</td>
<td>5%</td>
<td>15%</td>
<td></td>
</tr>
<tr>
<td>Repair Time</td>
<td>30 days</td>
<td>75 days</td>
<td></td>
</tr>
<tr>
<td>Casualty Rate</td>
<td>0.5%</td>
<td>1.5%</td>
<td></td>
</tr>
<tr>
<td>Probability of Unsafe Placard</td>
<td>10%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Repairability</td>
<td>98%</td>
<td>90%</td>
<td></td>
</tr>
<tr>
<td><strong>Risk Category IV – Healthcare (Hospital)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repair Cost</td>
<td>10%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td><strong>Repair Time</strong></td>
<td>45 days</td>
<td>100 days</td>
<td></td>
</tr>
<tr>
<td>Casualty Rate</td>
<td>0.5%</td>
<td>1.5%</td>
<td></td>
</tr>
<tr>
<td>Probability of Unsafe Placard</td>
<td>10%</td>
<td>25%</td>
<td></td>
</tr>
<tr>
<td>Repairability</td>
<td>95%</td>
<td>85%</td>
<td></td>
</tr>
</tbody>
</table>
tools for new design

Performance Estimation Tool (PET)

developed by Vesna Terzic, Ph.D.
CSU Longbeach
ATC-58-2 Performance Products Team
Performance Estimation Tool: PET

Preliminary design

Select strength and drift limits to meet performance objectives

- Probability of Unrepairable Permanent Drift
- Probability of Total Repairability
- Probability of Unsafe Placard
- Probability of Collapse
- Casualty Rate
PET Capabilities

Low-, mid-, and high-rise buildings

5 Lateral load-resisting systems

Office and Healthcare occupancies

Risk Categories II and IV

Three levels of seismic hazard w/ 5 shaking intensities

<table>
<thead>
<tr>
<th>Site Seismic Hazard</th>
<th>$S_{gs}$</th>
<th>$S_{df}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>High SDC D</td>
<td>1.33g</td>
<td>0.75g</td>
</tr>
<tr>
<td>Medium SDC D</td>
<td>1.00g</td>
<td>0.6g</td>
</tr>
<tr>
<td>Low SDC D</td>
<td>0.50g</td>
<td>0.35g</td>
</tr>
</tbody>
</table>
### Performance Objectives

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Design Earthquake</th>
<th>MCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median Repair Cost</td>
<td>5%</td>
<td>10%</td>
</tr>
<tr>
<td>90\textsuperscript{th} percentile Repair Cost</td>
<td>10%</td>
<td>20%</td>
</tr>
<tr>
<td>Median Repair Time</td>
<td>30 days</td>
<td>60 days</td>
</tr>
<tr>
<td>90\textsuperscript{th} percentile Repair Time</td>
<td>60 days</td>
<td>120 days</td>
</tr>
<tr>
<td>Probability of Unrepairable Permanent Drift</td>
<td>1%</td>
<td>3%</td>
</tr>
<tr>
<td>Probability of Unsafe Placard</td>
<td>5%</td>
<td>10%</td>
</tr>
<tr>
<td>Probability of Collapse</td>
<td>2%</td>
<td>5%</td>
</tr>
</tbody>
</table>

5-story (Midrise), Office Building
Risk Category II
SDC D ($S_D^S = 1.00g$, $S_D^1 = 0.60g$)
90th percentile Loss Ratio - SRCSW

From PET:
SRCSW Office
RC II
Midrise
SDC D

<table>
<thead>
<tr>
<th>Loss Ratio (%)</th>
<th>20% MCE</th>
<th>40% MCE</th>
<th>67% MCE</th>
<th>80% MCE</th>
<th>100% MCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Bound</td>
<td>0.4</td>
<td>4.7</td>
<td>11.1</td>
<td>17.7</td>
<td>34.7</td>
</tr>
<tr>
<td>Lower Bound</td>
<td>0.2</td>
<td>3.7</td>
<td>9.2</td>
<td>11.4</td>
<td>15.1</td>
</tr>
<tr>
<td>Current Search</td>
<td>0.2</td>
<td>4.2</td>
<td>9.5</td>
<td>12.0</td>
<td>16.9</td>
</tr>
<tr>
<td>Representative Design</td>
<td>0.2</td>
<td>4.3</td>
<td>9.7</td>
<td>12.2</td>
<td>16.5</td>
</tr>
</tbody>
</table>

Goal 10%: 9.2% ✓

Goal 20%: 11.1% NG

35% NG
Refine Design

Multiple of Minimum Base Shear

Design Story Drift

LEGEND

RDP
Range of Performance

CS
Current Search

RD
Representative Design

Casualty Rate (%)

Probability of Collapse vs. Intensity

Probability of Unreparable Permanent Drift vs. Intensity

Median Repair Time vs. Intensity

Median Loss, % Repl. Cost

FEMA P-58-7: Building the Performance You Need
# Performance Objectives

## Refine Design

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<tr>
<td>Median Repair Cost</td>
<td>5% ✓ 4.6%</td>
<td>10% ✓ 9%</td>
</tr>
<tr>
<td>90th percentile Repair Cost</td>
<td>10% ✓ 9.8%</td>
<td>20% ✓ 15.7%</td>
</tr>
<tr>
<td>Median Repair Time</td>
<td>30 days ✓ 21</td>
<td>60 days ✓ 29</td>
</tr>
<tr>
<td>90th percentile Repair Time</td>
<td>60 days ✓ 33</td>
<td>120 days ✓ 43</td>
</tr>
<tr>
<td>Probability of Unrepairable Permanent Drift</td>
<td>1% ✓ 0%</td>
<td>3% ✓ 0%</td>
</tr>
<tr>
<td>Probability of Unsafe Placard</td>
<td>5% ✓ 0.1%</td>
<td>10% ✓ 5.2%</td>
</tr>
<tr>
<td>Probability of Collapse</td>
<td>2% ✓ 0%</td>
<td>5% ✓ 0.4%</td>
</tr>
</tbody>
</table>

Design Drift = 0.44%

Design Base Shear = 2.5 x (Minimum Base Shear)
Following Steps

Design the considered systems

Compare construction costs

Select the system

Perform final design

*run PACT* for best estimate of performance
Seat at the Table
Building the Performance You Need

State-of-the-Art Tools for Seismic Design & Assessment