Owner Benefits From Smarter Building Design Using Voluntary Performance-Based Engineering

Saiful Islam, Ph.D., S.E., Matthew Skokan, Ph.D., S.E., and Tom Bouquet, S.E.
## Code-Based vs. Performance-Based Seismic Design

<table>
<thead>
<tr>
<th>CODE-BASED SEISMIC DESIGN</th>
<th>PERFORMANCE-BASED SEISMIC DESIGN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prescriptive code criteria.</td>
<td>Generally uses sophisticated computer models based on latest research along with site-specific estimate of earthquake ground shaking.</td>
</tr>
<tr>
<td>Relatively simple to implement.</td>
<td>Significantly more engineering intensive.</td>
</tr>
<tr>
<td>Restricts use of research, technology and innovations to achieve desired seismic performance economically.</td>
<td>Provide greater assurance that building design will meet intended seismic performance objectives.</td>
</tr>
<tr>
<td>No direct link between the intended seismic performance and the prescriptive requirements of the code.</td>
<td>More “Predictable” and “Defined” Seismic Performance.</td>
</tr>
<tr>
<td></td>
<td>Requires Peer Review when mandated by the Code.</td>
</tr>
</tbody>
</table>
Voluntary Performance-Based Seismic Design

BUILDING DESIGN

Primary Structure

Code-Based Design

Fail

Performance Based Evaluation

Pass

Final Primary Structure Design Meets Code + Performance Based Design

Submit Code-Based Design to Building Official for Approval

Advantages

- PBSE provides greater assurance of desired seismic performance
- Owner is engaged in decision making process related to seismic performance
- Eliminates need for lengthy & costly peer-review process
- Owner may benefit in reduced costs to achieve higher seismic performance
LAX Midfield Satellite Concourse (MSC)
LAX Midfield Satellite Concourse (MSC)
LAX Midfield Satellite Concourse (MSC)

- Steel Special Moment Resisting Frames w/ RBS Connections
- Basement Concrete Shear Walls
Many airports/terminals designed using prescriptive code-based seismic requirements as an “Essential Facility” with an Importance Factor of $I = 1.5$.

**LAX MSC Design Approach**

1. Prescriptive code-based seismic design as a Risk Category III building with an Importance Factor of $I = 1.25$.
2. Performance-Based Seismic Design to meet the Seismic Performance Objectives for an “Essential Facility.”
### Seismic Performance Objectives

#### Earthquake Hazard Level

- **EQ Level 1**
  - Frequent
  - (43-yr EQ or 50% / 30yrs)

- **EQ Level 2**
  - Rare
  - (475-yr EQ or 10% / 50yrs)

- **EQ Level 3**
  - Very Rare
  - (2,475-yr EQ or 2% / 50yrs)

#### Building Performance Level

- **Operational**
- **Immediate Occupancy**
- **Life Safety**
- **Collapse Prevention**

- **Enhanced Performance**
  - (LAX MSC)

- **Typical Buildings**
Moment Frame Behavior

**Code-Based** design allows moment frames to have both beam hinging and panel zone yielding.

**Performance-Based Design for Immediate Occupancy** allows beam hinging, but **no** panel zone yielding.

No Yielding of Panel Zone Allowed for Immediate Occupancy
LAX MSC – Original Code-Based Design

475-yr EQ / Immediate Occupancy

Several panel zones do not satisfy the Immediate Occupancy limit.
LAX MSC – Performance-Based Design

475-yr EQ / Immediate Occupancy

Panel Zone Shear Deformation
LAX MSC – Performance-Based Design

475-yr EQ / Immediate Occupancy

Longitudinal (H1) Direction

- GM1
- GM2
- GM3
- GM4
- GM5
- GM6
- GM7
- Average

Height (ft)

Interstory Drift Ratio (%)

Transverse (H2) Direction

- GM1
- GM2
- GM3
- GM4
- GM5
- GM6
- GM7
- Average

Height (ft)

Interstory Drift Ratio (%)

High Roof

Low Roof

Sterile

Concourse

Apron

LAX Midfield Concourse Building A2
Beam Plastic Rotation

Typical 0.006

\[ M_u \]
\[ M_y \]
\[ 0.2M_y \]

Range

\[ \theta \] (rad.)

\[ \approx 0.02 \]
\[ \approx 0.045 \]
\[ \approx 0.06 \]

0.5% Plastic Rotation
Test: W36x150 Bm / W27x194 Col

1% Plastic Rotation
Test: W24x62 Bm / W14x176 Col

LAX MSC – Performance-Based Design

475-yr EQ / Immediate Occupancy
LAX MSC – Performance-Based Design

2,500-yr EQ / Life Safety

Beam Plastic Rotation

Typ. 0.025

2.5% Plastic Rotation
Test: W36x150 Bm / W27x194 Col

4% Plastic Rotation
Test: W36x150 Bm / W14x398 Col

Range

Typ. 0.02
≈ 0.045
≈ 0.06

(rad.)

\( \theta \)
LAX MSC – Performance-Based Design

2,500-yr EQ / Life Safety

Panel Zone Shear Deformation
LAX Terminal 1.5
LAX Terminal 1.5

Terminal 1
Terminal 1.5
Terminal 2
LAX Terminal 1.5

- Steel Special Moment Resisting Frames w/ Sideplate Connections
- Basement Concrete Shear Walls
- Importance Factor = 1.25
LAX Terminal 1.5

Basement / Main Electrical & Pump Rooms

Arrivals Baggage Claim

Departures / Ticketing

Concourse / SSCP Secure Area

SWA & LAWA Offices

Roof / Mechanical Enclosure
Several Columns do not satisfy the Life Safety Limit

LAX T1.5 – Original Code-Based Design

2,500-yr EQ | Life Safety

Moment Frame Columns
LAX T1.5 – Performance-Based Design

2,500-yr EQ / Life Safety

Revised to W27x336
LAX T1.5 – Performance-Based Design

475-yr EQ / Immediate Occupancy

Average of 7 EQs.

LAX T1.5 – Performance-Based Design

475-yr EQ / Immediate Occupancy

Average of 7 EQs.
LAX T1.5 – Performance-Based Design

475-yr EQ / Immediate Occupancy

Beam Plastic Rotation

Typ. 0.4%

~1.8%  ~5.2%  ~7.0%

Test: W36x150 Bm / W36x231 Col

1.5% Plastic Rotation

M

M\_\text{max}

M\_\text{pe}

M\_\text{Fall}

IO  LS  CP

~1.8%  ~5.2%  ~7.0%

LAX T1.5 – Performance-Based Design

475-yr EQ / Immediate Occupancy
LAX T1.5 – Performance-Based Design

2,500-yr EQ / Life Safety

Beam Plastic Rotation

Test: W36x150 Bm / W36x231 Col

3.5% Plastic Rotation

Typ. 2.0%

~1.8%  ~5.2%  ~7.0%

M

M_{max}

M_{pl}

M_{fall}

IO  LS  CP
LAX T1.5 – Performance-Based Design

2,500-yr EQ / Life Safety

All Columns satisfy the Life Safety limit
Caltech Chen Neuroscience Research Building

- Buckling Restrained Braced Frames
- Basement Concrete Shear Walls
- Importance Factor = 1.25
Caltech Chen Neuroscience Research Building

475-yr EQ / Life Safety

Fault Normal

Avg. Range (4.5~5.5)
Level 3 - R

Avg. Range (5.1~6.1)
Level 2 - 3

Avg. Range (5.1~5.8)
Level 1 - 2
Caltech Chen Neuroscience Research Building

2,500-yr EQ / Collapse Prevention

Caltech Chen Neuroscience Research Building

Fault Normal
Caltech Chen Neuroscience Research Building

Earthquake Hazard Level

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<tr>
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<th>Operational</th>
<th>Immediate Occupancy</th>
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<th>Collapse Prevention</th>
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<tr>
<td>Frequent (43-yr EQ or 50% / 30yrs)</td>
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<table>
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<tr>
<th>EQ Level 2</th>
<th>Operational</th>
<th>Immediate Occupancy</th>
<th>Life Safety</th>
<th>Collapse Prevention</th>
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<tbody>
<tr>
<td>Rare (475-yr EQ or 10% / 50yrs)</td>
<td></td>
<td></td>
<td></td>
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<table>
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<tr>
<th>EQ Level 3</th>
<th>Operational</th>
<th>Immediate Occupancy</th>
<th>Life Safety</th>
<th>Collapse Prevention</th>
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<tbody>
<tr>
<td>Very Rare (2,475-yr EQ or 2% / 50yrs)</td>
<td></td>
<td></td>
<td></td>
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</table>
Thank you!