PEER 2003 ANNUAL MEETING
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Performance Based Earthquake Engineering

"From Assessment to Design"

Presented By:

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PBEE

PEER'S Focus

Current: Assessment

Future: Design

- Retrofit Design
- New Building Design

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Practice Perspective

- of PBEE Today
- of PEER's Next Steps
- of PBEE in the Future

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Engineering Science Comments

- PBEE Assessment Process
- PBEE Design Process

Social Science Comments

- Constituents
- Communication
- Universality of PBEE

Practice Comments

- Predicting Damageability
- Detailing
- Contemporary Architecture

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“Performance”

- Do We Define it the Same Way?
- Do We Use it the Same Way?
- Do Constituent “Users” Understand How We are Using It?

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The “Performance” Menu

- Immediate Occupancy
- Life Safety
- Collapse Prevention

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Performance

- Immediate Occupancy
  - High Performance
  - Essential Services Buildings
  - Damage - Free

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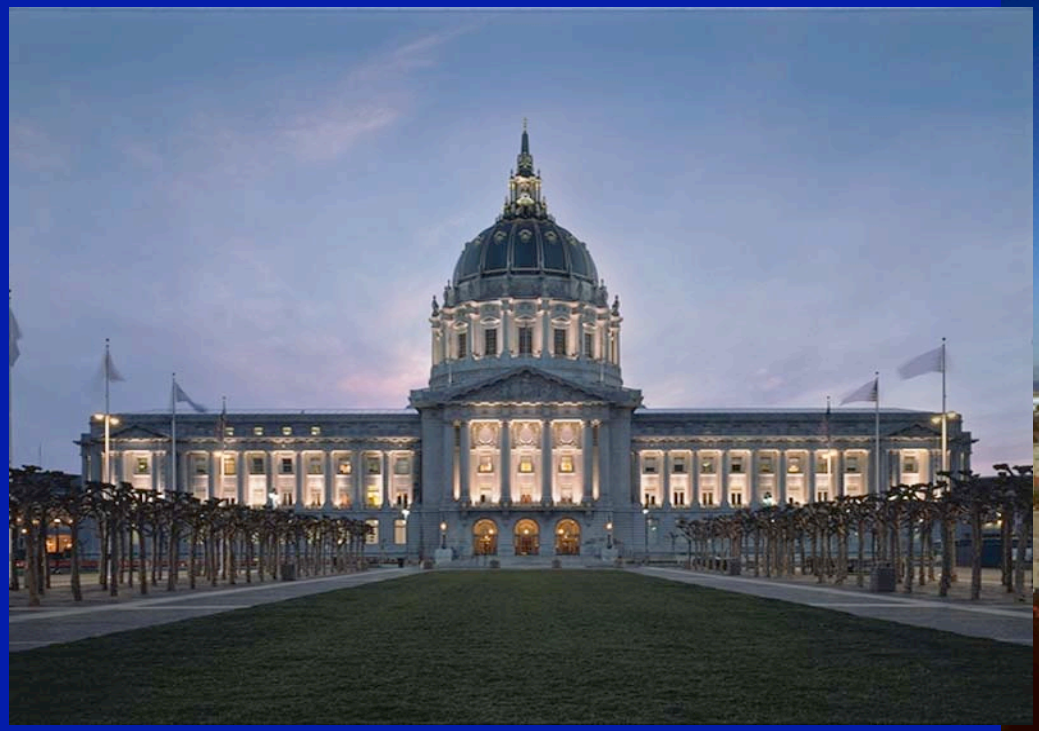
Performance



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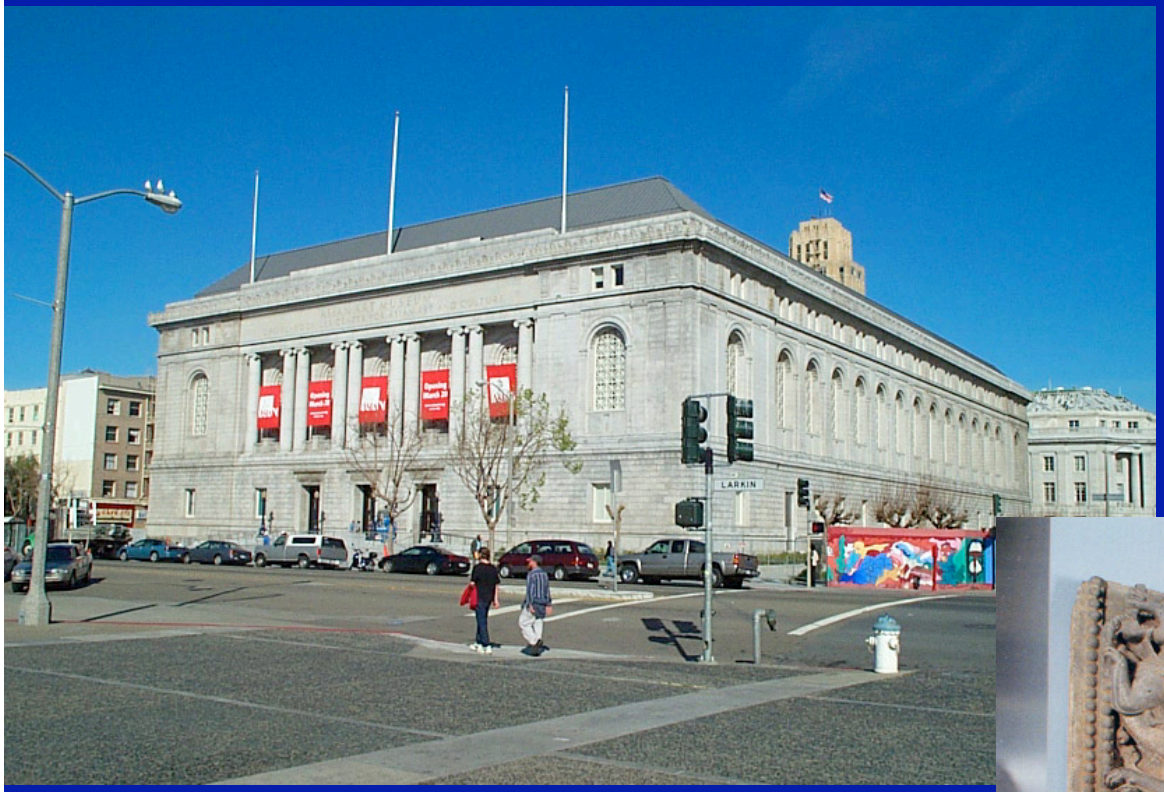
Performance



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Performance

- Life Safety
  - Building Code Mandate
  - Safe Egress
  - Accepts Damage

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Performance

- Collapse Prevention
  - Less Than Code?
  - Safe Egress
  - Lots of Damage
    - Total Economical Loss

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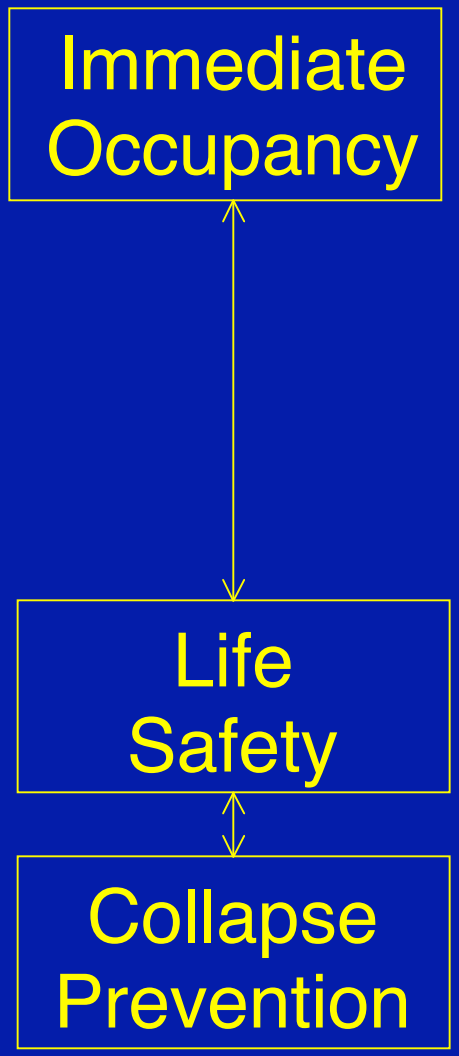
Performance Level



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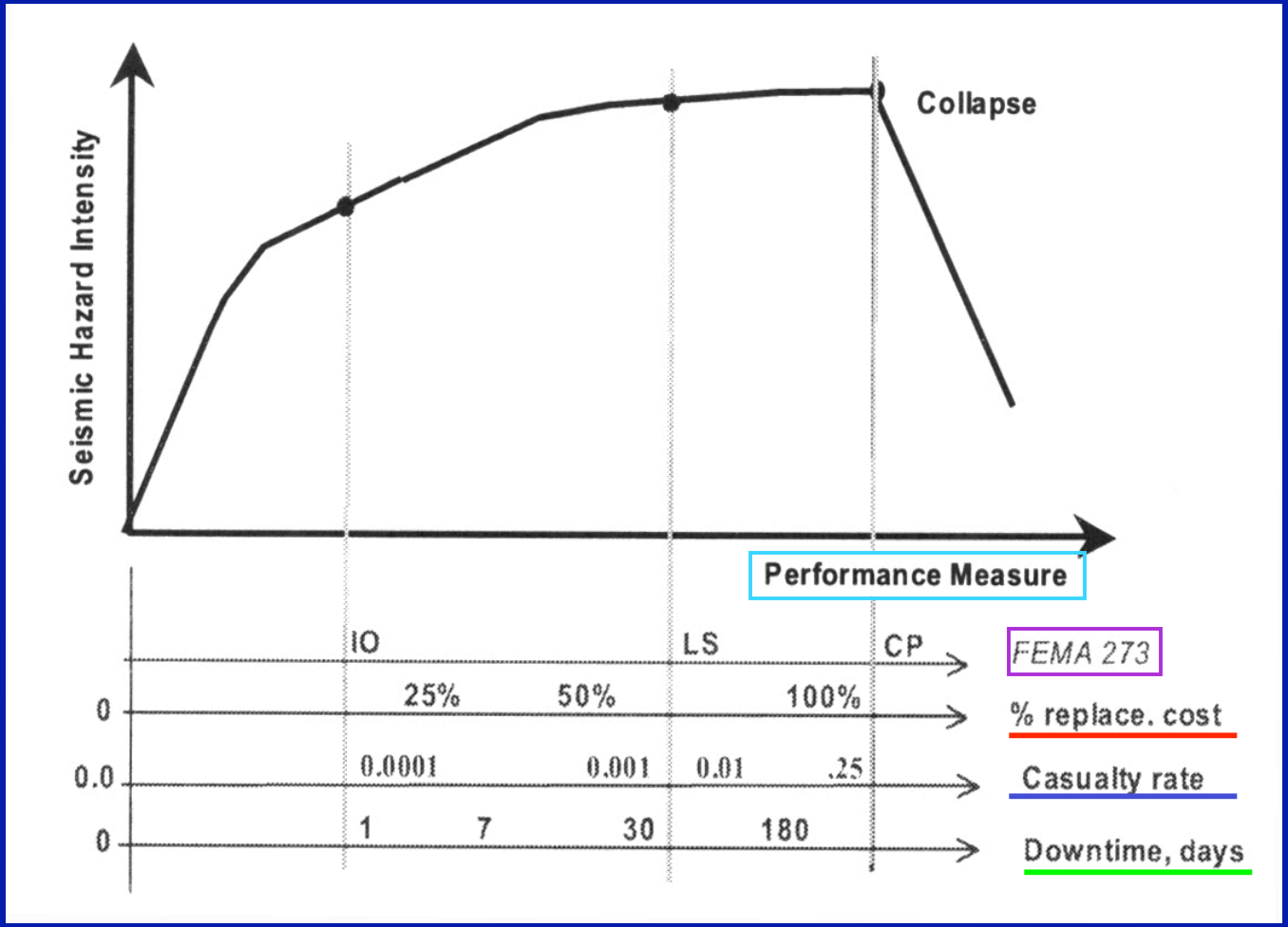
PEER PBEE Assessment Process

The Idealized Pushover Curve



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PEER PBEE
Probability Framework Equation

$$\lambda(DV) = \iiint G\langle DV \mid DM \rangle dG\langle DM \mid EDP \rangle dG\langle EDP \mid IM \rangle d\lambda(IM)$$

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Decision Variable (DV)

- Economic Loss
- Downtime
- Casualty Rate

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The Variable Parameters

- Intensity Measure (IM)
- Engineering Demand (EDP) Parameter
- Damage Measures

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Intensity Measure (IM)

- Peak Ground Acceleration
- Spectral Acceleration

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Engineering Demand Parameters

- Relative To:
  - Performance Target
  - Type of Structural System
- Typical EDP's:
  - Story Drift
  - Inelastic Deformations
  - Floor Accelerations
  - Ductility – Hysteretic Energy Dissipation

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Damage Measures

- Damage States Repair
  - Minor
  - Moderate
  - Severe

- Fragility Curves
  - Primary Structure
  - Secondary Structures
  - Architectural Elements
  - Systems – Life Safety
  - Contents

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Fragility Curve For Gypsum Partition

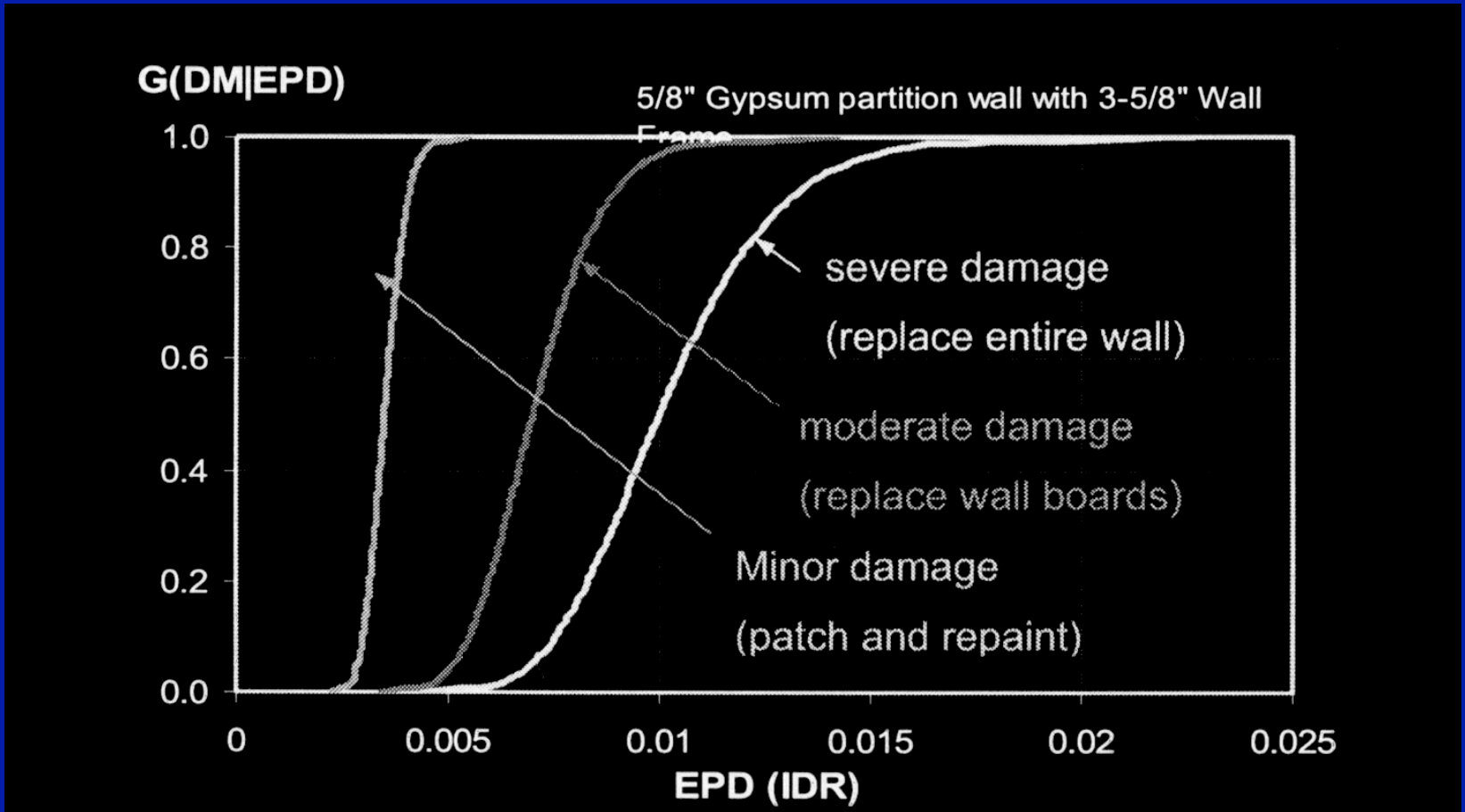

Figure 8 – Example of EDP to DM fragility curves for gypsum wall

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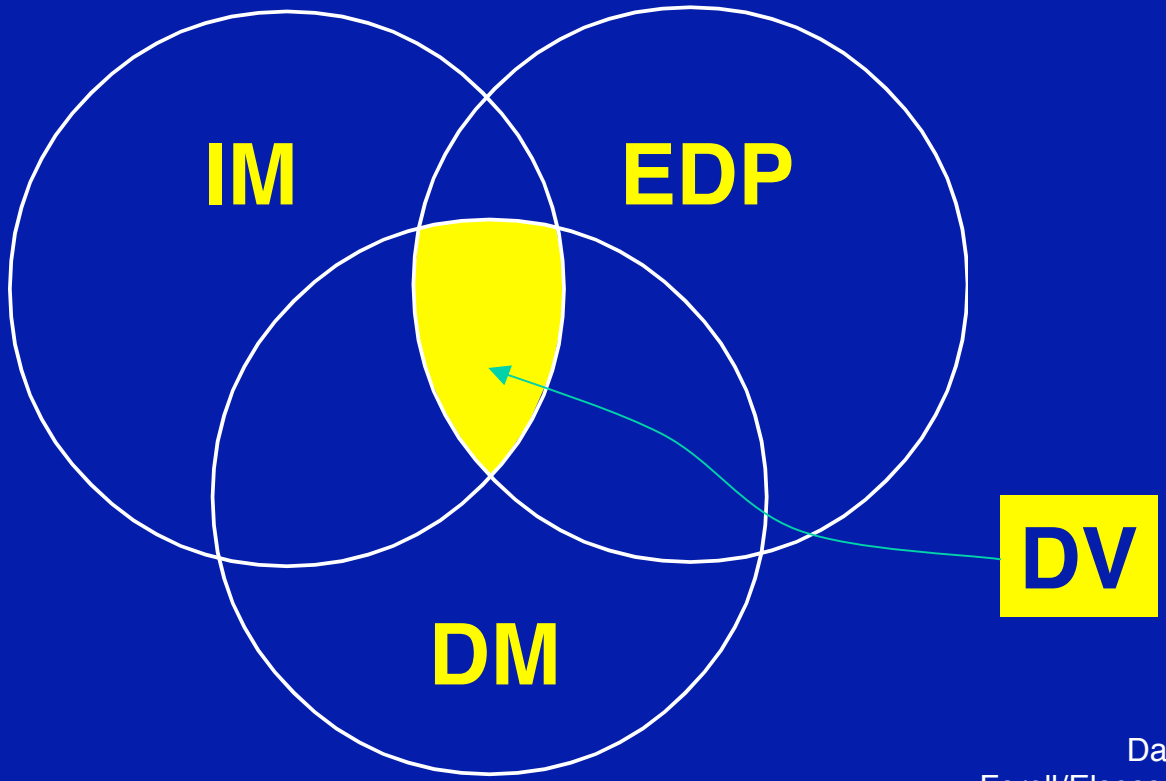
Simplified Equation

$$DV \sim \square(IM, EDP, DM)$$



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Assessment PBEE Process

Answer: Decision Variable

Knowns: IM, DM, EDP

Constituents: Structural Engineer
Seismologists
Building Owner

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Design PBEE Process

Answer: EP

Knowns: DV, IM, DM

Constituents: Structural Engineer
Seismologists
Building Owner
Users
Architects

EDP ~ f (DV, IM, DM)

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PBEE Framework For New Buildings

Step 1: Define Decision Variables

- Owner selects desired level of seismic protection in terms of decision variables ($, loss, downtime)

Step 2: Correlate Decision Variables to Damage Measures

- Select performance level (IO, LS, CP, ??)

Step 3: Relate Damage Measures to Specific Engineering Demand Measures

- Develop relations for modern building systems which show performance levels under various engineering demand parameters. (Refinement of fragility curves)

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PBEE Framework For New Buildings

Step 4: Use EDP's to Define System-Level Target Design Parameters

- For different earthquake probabilities, create a set of EDP acceptabilities (initial period, design base shear, maximum interstory drift ratio, floor accelerations)

Step 5: Define Seismic Hazard at Site

- Defines family of demand curves

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PBEE Framework For New Buildings

Step 6: Given Site-Specific Earthquake Demands (IM, Sa, MMI, PGA), Verify Performance and Develop System-Level Demand Parameters

- System-Level Demand Parameters

  - Target Initial Period
  - Base Shear

  〉 Common Design Parameters for (N) Buildings

Step 7: Refine System-Level Parameters

- Use Non-Linear Analysis to Verify Performance Using the Above Design Parameters

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PBEE Constituents

Mission: "Improve Seismic Risk Decision Making"

- Seismologists
- Structural Engineers
- Building Owners

- Municipalities
- Users / OCCUPANTS
- ARCHITECTS
- Contractors
- M/E/P Systems Engineers
- ……..

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PBEE Constituents

The Point:

A large array of stakeholders

Question 1:

Are we addressing the interests/perspectives of all constituents?

→ Sustainability

Question 2:

Can PBEE Methodology be broad enough and comprehensive enough to deliver the seismic performance we think we are designing?

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Communication of PBEE Methodology

How Do We Communicate PBEE?

- Probability:

  "Mean annual probability of experiencing an earthquake loss that would exceed X% of the replacement value of the facility"

- Acronyms:

  EDP, IM, NLTHA, IDA, ……..

- Terminology:

  Component Inelastic Deformations
  Floor Accelerations
  Hysteretic Energy Dissipation

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Communication of PBEE Methodology

How Do We Communicate PBEE:

- Assertion:

  If PBEE is going to be effective, it will need to be clearly communicated and understandable to both technical and lay audiences

- The Need:

  A clear and simple lexicon of PBEE terminology

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Universality of PBEE

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Universality of PBEE

- Who Are the Current Users of PBEE?
- Is the PEER Audience “Preaching to the Already Converted”?
- Are the Engineering Users the “Tip of the Iceberg”?
- What About the Other 90% of the Structural Engineering Community?
- How Much Time and Design Fees Will Be Consumed By the PBEE Methodology?

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Universality of PBEE

The Goal:

- PBEE as a Universal Tool

The Challenges:

- PBEE Methodology must be at once rigorous and simplified.
- PBEE Methodology must be clear, straight-forward, and easily understood by 100% of the earthquake engineering community.
- PBEE Methodology must be “affordable” within the constraints of structural engineering fee structures.

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Predicting Damageability

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Predicting Damageability

- How accurate are we in predicting and describing damage?
- Is the total damage simply a summation of all of the predicted component damage?
- Do we keep in mind all the applicable components?
  - Primary Structure
  - Secondary Structure
  - Architectural Finishes
  - Life Safety Systems
  - Contents
- Does construction quality affect damageability?
- Is all damage repairable?

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Predicting Damageability

The Goal:

- Gain confidence in predicting and quantifying damage to all components of a building.

The Challenge:

- Expand our database of fragility curves.
- Maintain a holistic view of damage and consideration of all components.
- Be valiant of assumptions and qualifications: How does construction quality affect performance?

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Performance & Detailing

- Good performance is certainly correlated to quality of design and detailing.
  - Clear and Consistent Load Path
  - Reliable and Robust Connectivity

- "The Devil is in the Details"

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Performance & Detailing

- PBEE and PEER should focus some attention to appropriate component detailing.

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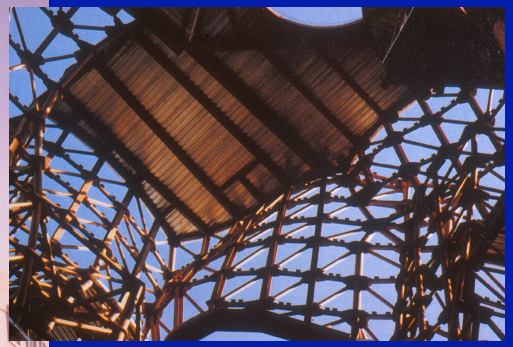
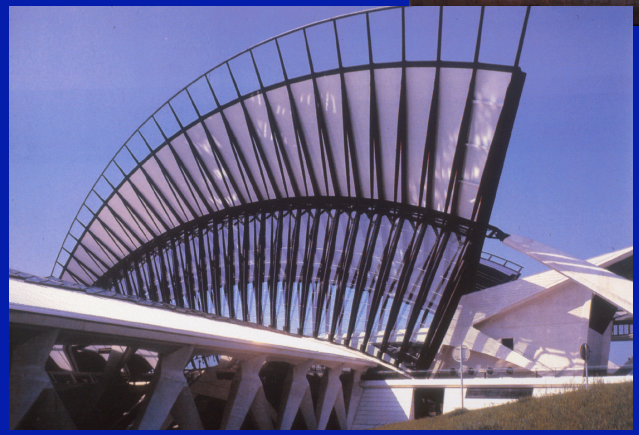
PBEE ⟷ Contemporary Architecture





- PBEE Methodology must work for these buildings or PBEE will not be successful.

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Conclusions & Recommendations

- PBEE has a solid foundation, greatly assisted by PEERS's work on assessment methodology.
- PEER is continuing to build and refine the PBEE methodology, appropriately transitioning efforts from assessments to design.
- PBEE methodology for design is doable, but it will be trickier than assessment methodology.
  - More"Players"
  - Greater Range of Variables and Probabilities
  - More Unknowns

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Conclusions & Recommendations

Though scientifically based, PEER must keep a holistic view of PBEE in devising a utilitarian methodology:

- Development of database of fragility curves to improve our ability to predict and define damage.
- PBEE methodology must consider and "speak" to a greater array of constituents, particularly users and architects.
- Improved, user-friendly lexicon for communicating PBEE methodologies to non-technical constituents.

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Conclusions & Recommendations

- Clear and simplified PBEE methodologies for broader use by the earthquake engineering community.
- Consider the elements of detailing that correlate to performance and include into the methodology.
- Use contemporary architectural forms as a litmus test for the PBEE process.

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Conclusions & Recommendations

Last, But Not Least

- PBEE Must be –

  CLEAR & ORDERED, NOT CHAOTIC.

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