



2003 PEER Annual Meeting

*Issues and Needs for  
Implementing Performance-based  
Approaches in Engineering Practice*

By:

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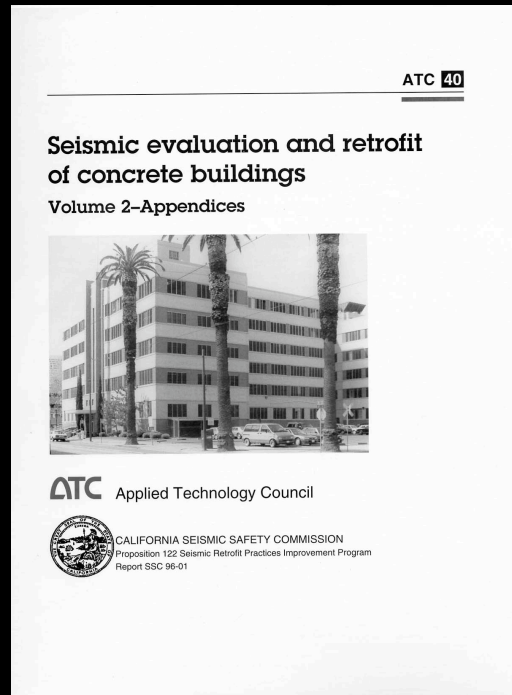
**SGH**

Simpson Gumpertz & Heger Inc.  
Consulting Engineers  
Boston / San Francisco / Washington DC

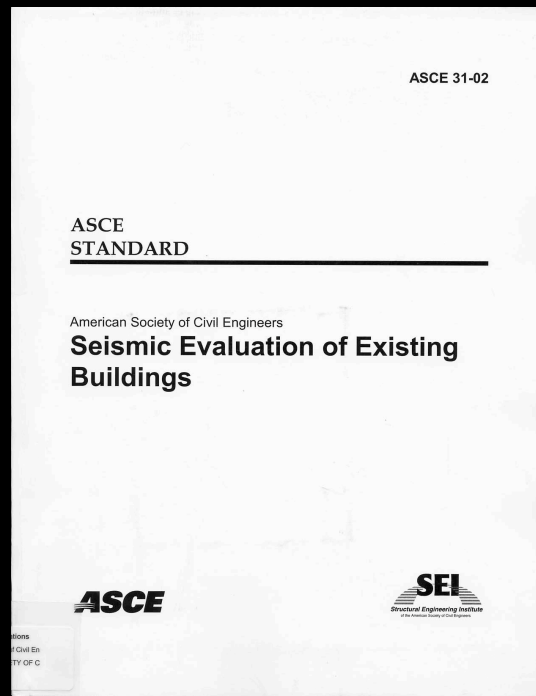
# Discussion Topics

- Current State of Practice
  - \_ Procedure
  - \_ Problems
- ATC-58 Project
  - \_ Vision
  - \_ Needs

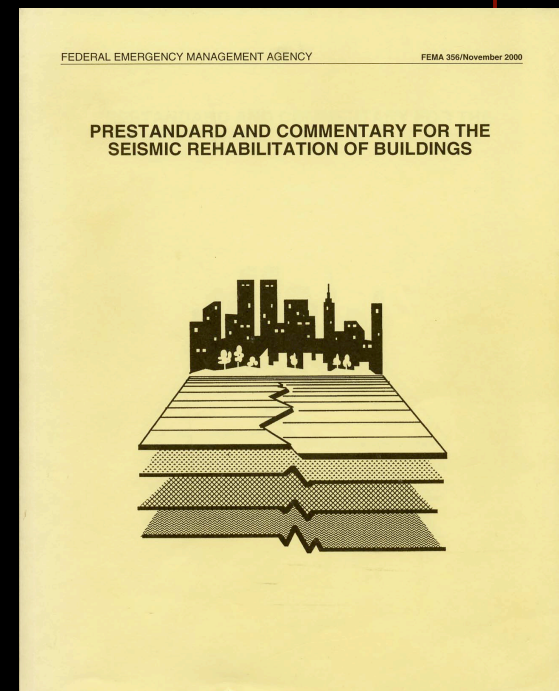
# Current State of Practice



ATC-40



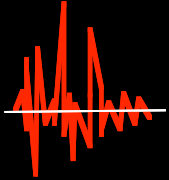

ASCE-31

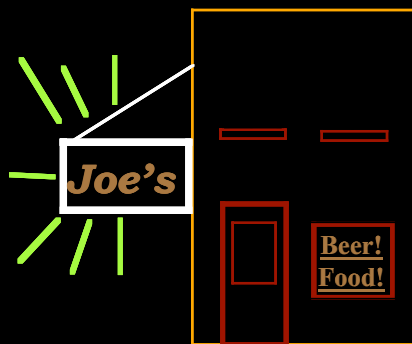


FEMA-356

# Current Process

## Step 1 – Define Performance Objective

**Performance Objective** =  +   
Ground Motion      Performance Level  
x% - 50 years



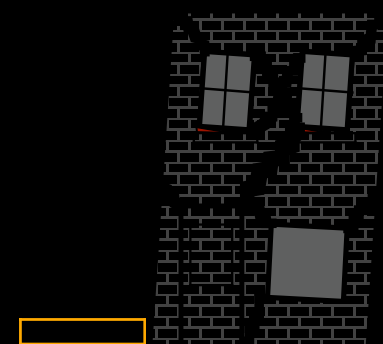
Operational



Immediate Occupancy

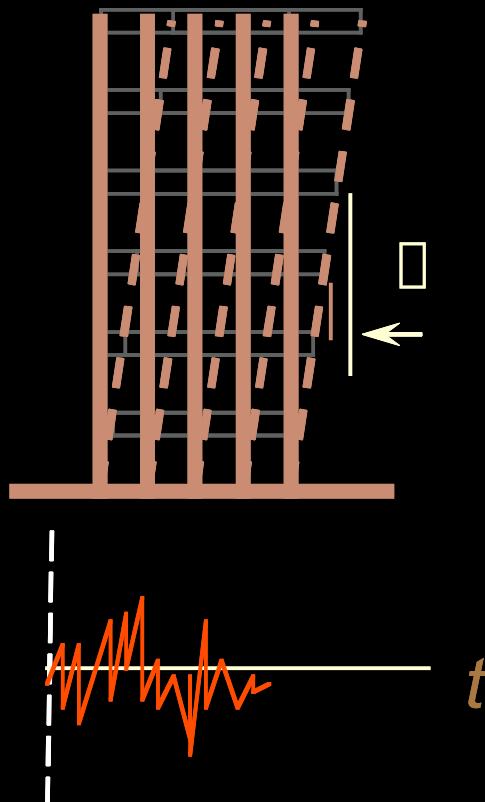


Life Safety



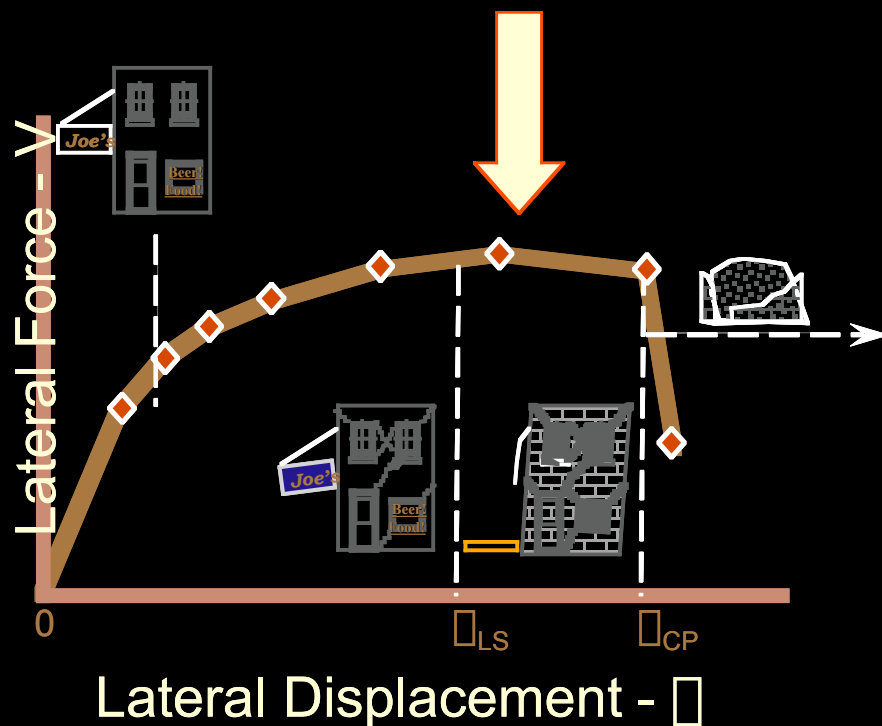
Collapse Prevention

## Step 2 – Perform Analysis



- Predict Response Parameters:
  - Strength demand on elements
  - Inelastic deformation or ductility demand on elements
  - Interstory drift ratios

# 3- Evaluate Performance



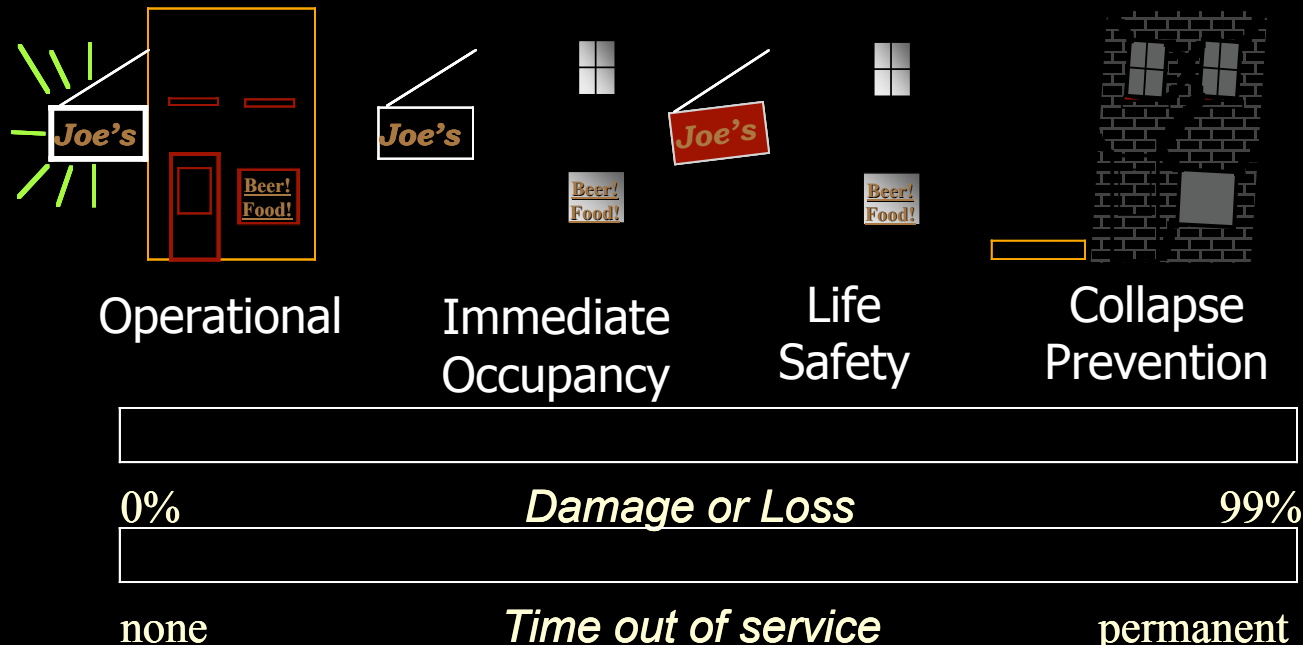
- Comparing individual element strength and deformation demands against tabulated "acceptable" values
- Acceptable values based on:
  - Element type & detailing
  - Element importance
  - Performance Level

# Current Practice - Benefits

- Relatively simple to implement
- Encourages engineers to think in nonlinear manner
  - \_ Identify damage/failure modes
  - \_ Evaluate significance
- Clear improvement over past linear, code-based approaches

# Current State – Problems

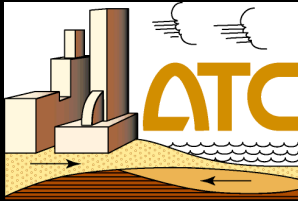
- Standard Performance Levels don't directly relate to "consequences" of interest to consumer
  - Number of lives lost
  - \$ repair cost
  - Days lost occupancy





# Current State - Problems

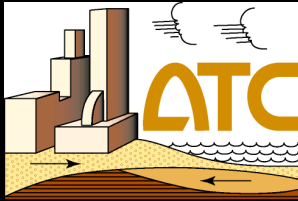
- Performance evaluation is based on “element” behavior, not global behavior
- Much of the acceptance criteria is based on judgment rather than data
- Reliability of guidelines is unknown
  - Potential liability problems associated with owner perception of “performance warranty”
- Guidelines appear to produce designs that are quite conservative compared with traditional practice



# ATC-58 Project



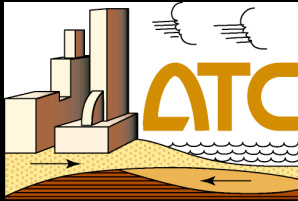
- Develop a next-generation of performance-based seismic design guidelines
- Applicable to:
  - \_ Design of new buildings
  - \_ Upgrade of existing buildings
- Compatible with parallel efforts in:
  - \_ Blast Engineering
  - \_ Fire Engineering



# ATC-58 Project Tasks



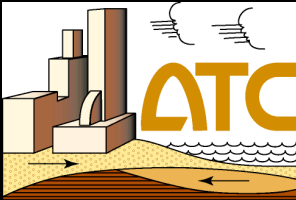
- Performance communication lexicon that is meaningful to stakeholders
- Building performance prediction engine
  - \_ Using performance communication lexicon
- Design performance levels and objectives
  - \_ Using performance communication lexicon
- Practical design procedures
- Comparison with current prescriptive approaches
- New prescriptive procedures



# ATC-58 Limitations



- No Basic Research
- Draw upon and incorporate latest research performed by others
- Reach engineering consensus as to suitability and appropriate application of available technologies
- Develop practical guidelines for use in engineering applications

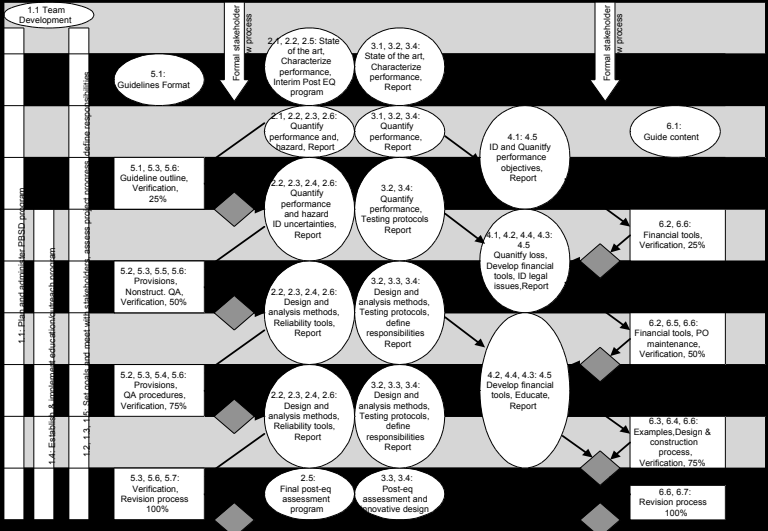


# Project Work Plan

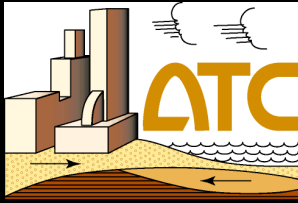


Federal Emergency Management Agency FEMA-349

## Action Plan: Performance-based Seismic Design



\$20-27 Million  
10 year Development Schedule



# ATC-58 Products



Federal Emergency Management Agency FEMA-349

## Seismic Performance Prediction for Buildings

Operational    Immediate Occupancy    Life Safety    Collapse Prevention

Performance Evaluation Method

Federal Emergency Management Agency FEMA-349

## Guidelines for Performance-based Seismic Design

Operational    Immediate Occupancy    Life Safety    Collapse Prevention

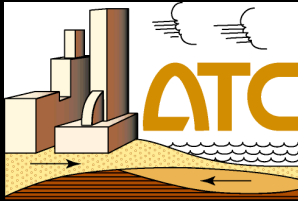
Guidelines for Performance Design

Federal Emergency Management Agency FEMA-349

## Recommended Prescriptive Seismic Design Criteria

Operational    Immediate Occupancy    Life Safety    Collapse Prevention

Prescriptive Criteria for Design



# ATC-58 Products



Federal Emergency Management Agency FEMA-666

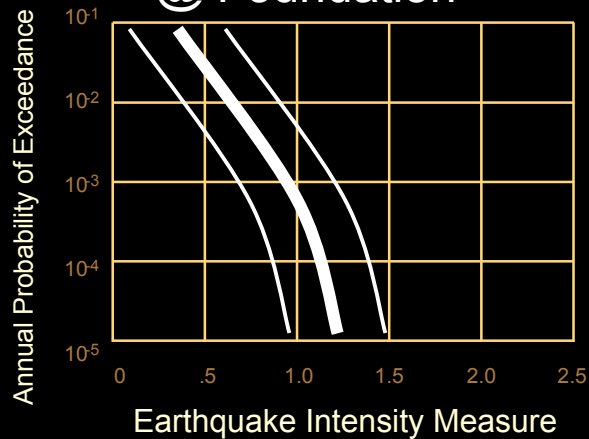
## Stakeholders Guide to Seismic Performance Selection



- Many types of stakeholders
  - Developers
  - Corporate Tenants
  - Insurers
  - Lenders
  - Institutions
  - Public Agencies
  - Building Regulators

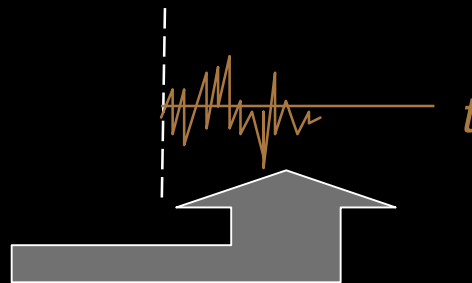
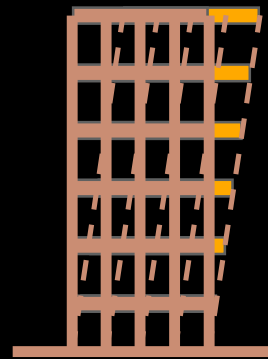
# Building Performance Engine

Hazard Function for  
Earthquake  
Intensity Measure  
@ Foundation

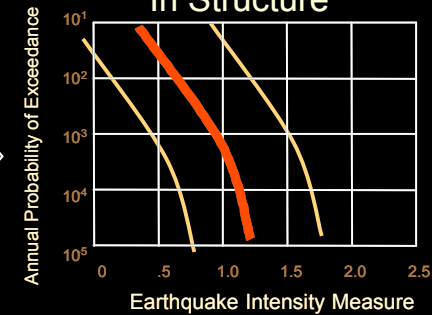


- MMI
- pga
- $S_a(T_1)$
- $S_a\{T_1, T_2\}$
- $S_a\{T_1, T_2\}, \text{Duration}$

Run  
Analysis



Hazard Function for  
Earthquake  
Intensity Measure  
In Structure

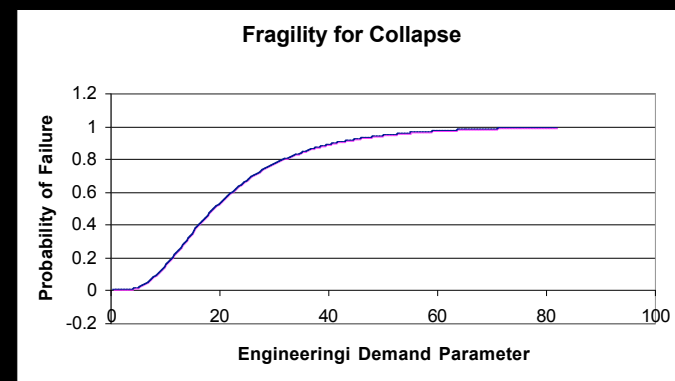
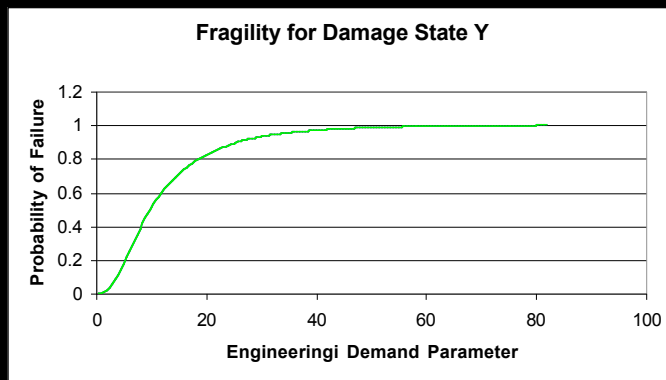
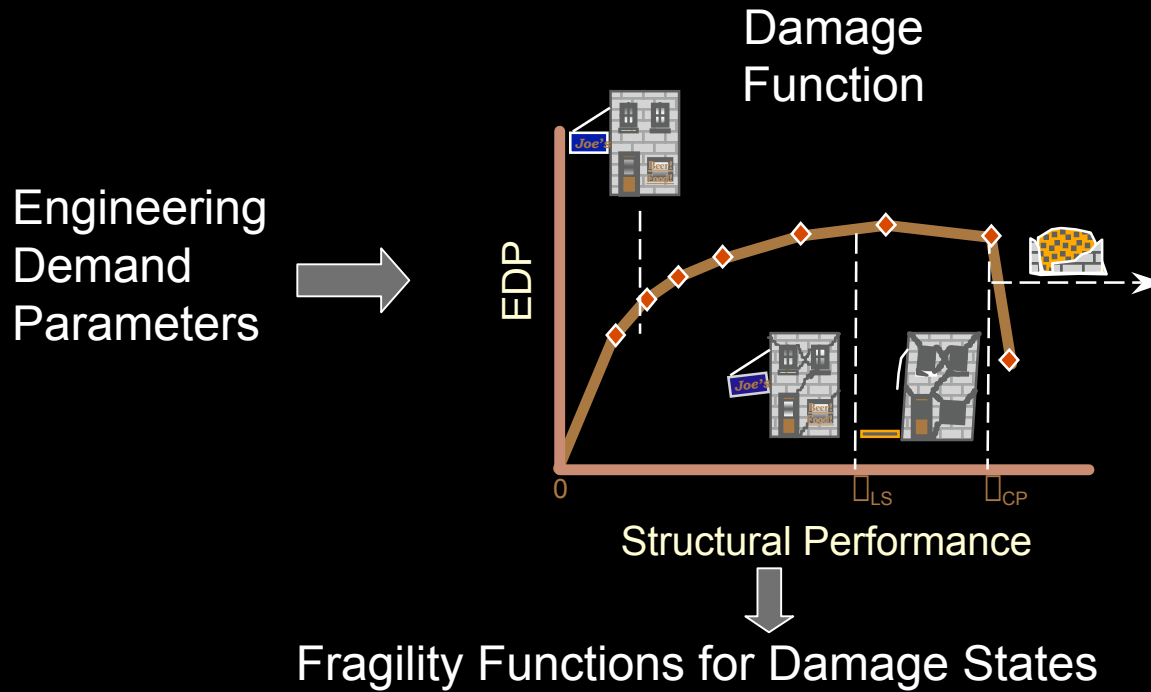


Engineering  
Demand  
Parameters

- Interstory Drift
- Plastic Rotation
- Element Force
- Cumulative Energy

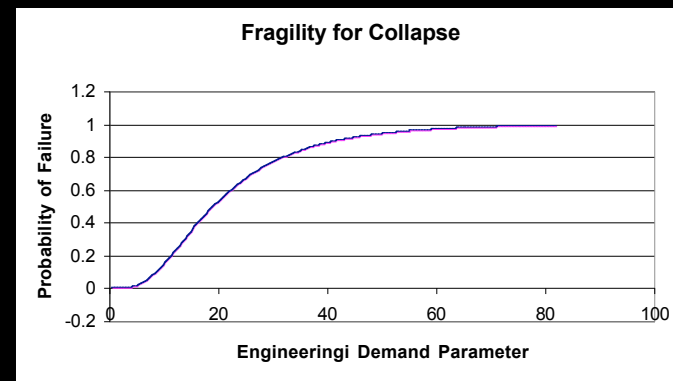
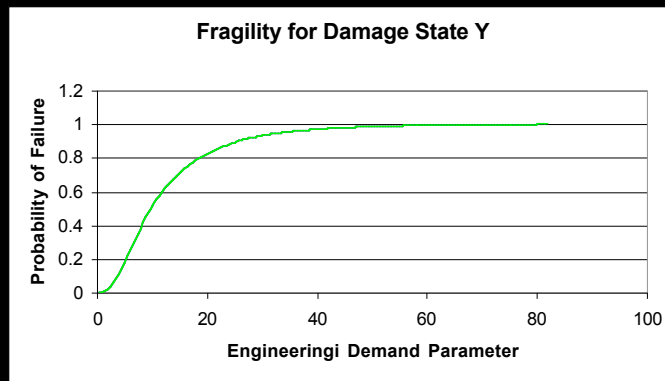


# Building Performance Engine

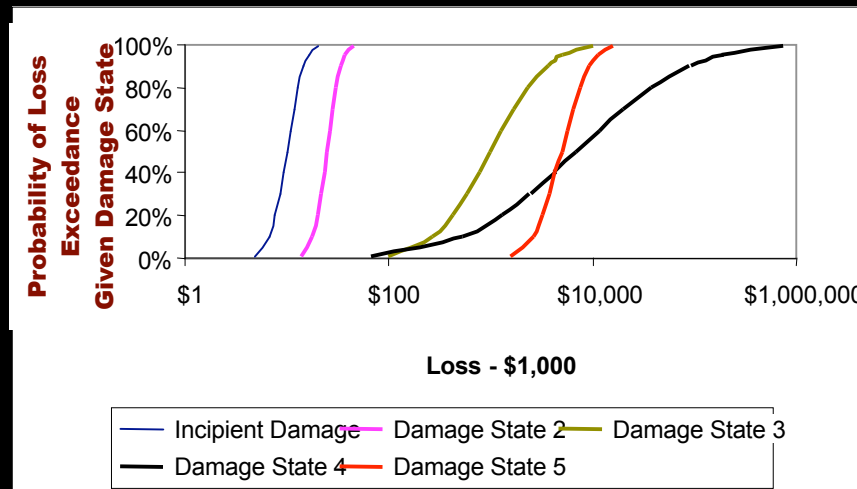


# Building Performance Engine

## Fragility Functions for Damage States

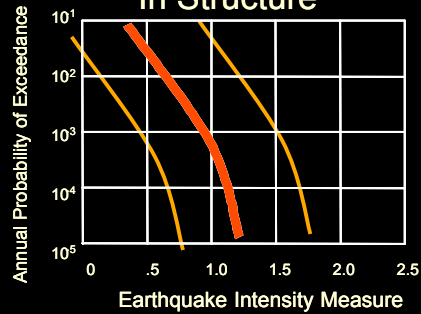


Loss Function

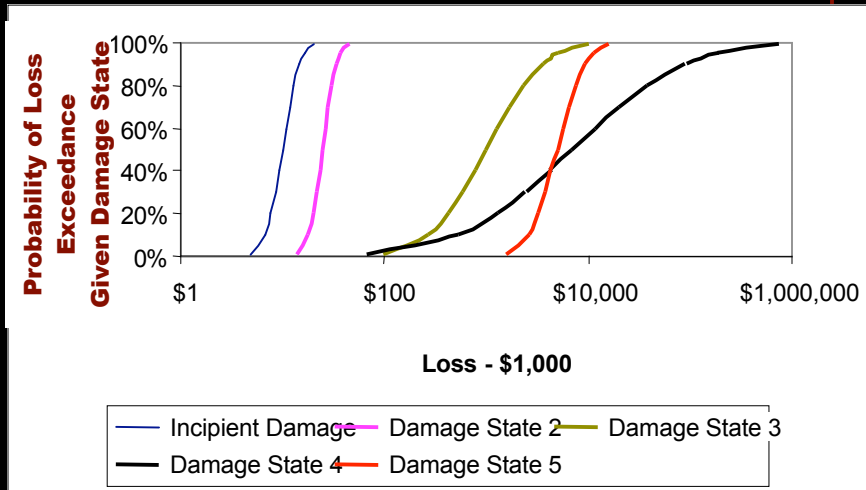
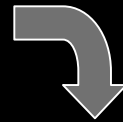


# Building Performance Engine

Hazard Function for Earthquake Intensity Measure In Structure



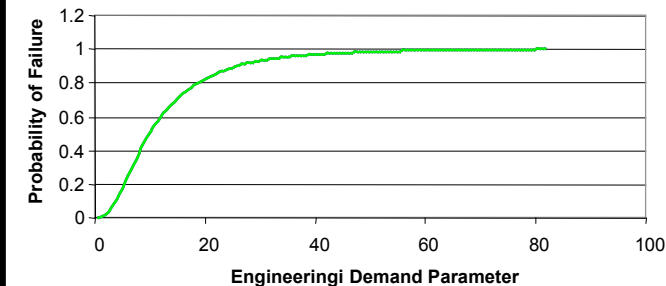
Loss Function



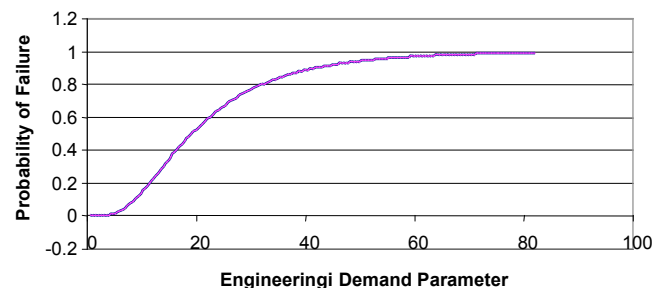
Fragility



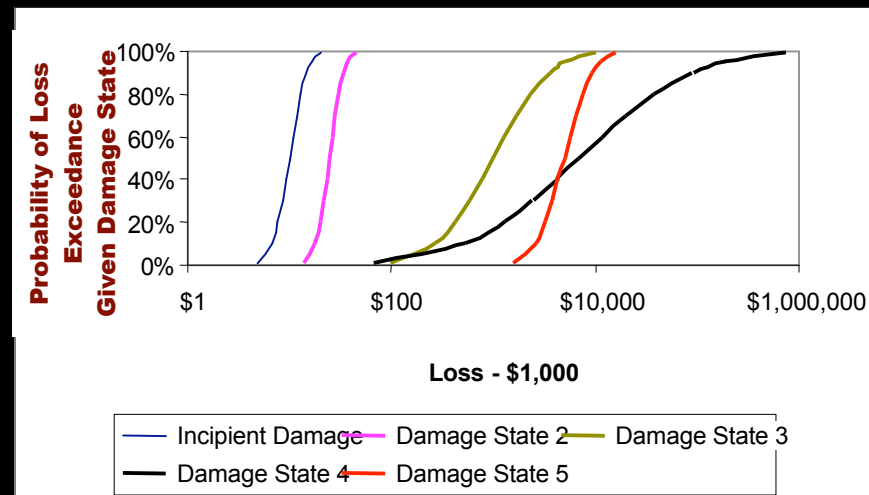
Fragility for Damage Loss of Function



Fragility for Overturning



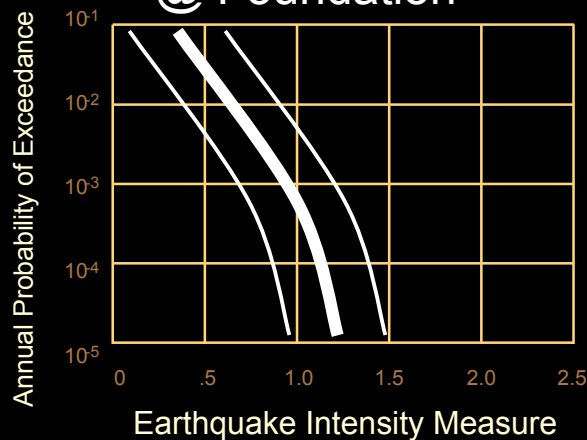
# Loss Functions



- Average annual loss
- Probability of exceeding loss of given amount
- Probable loss given scenario event
- Maximum probable loss
- Maximum foreseeable loss

# Needs – Intensity Measures

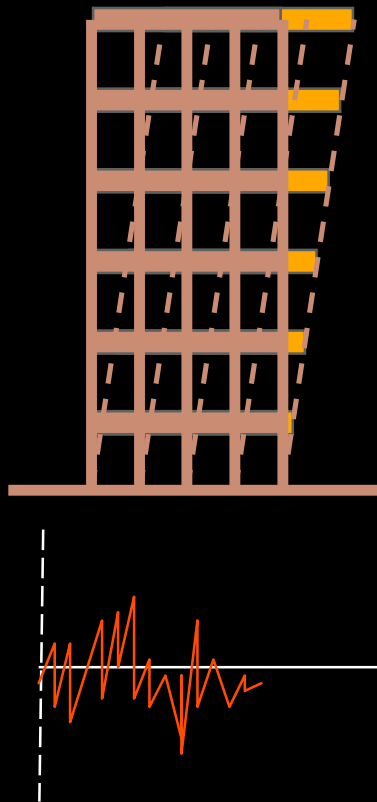
Hazard Function for  
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- MMI
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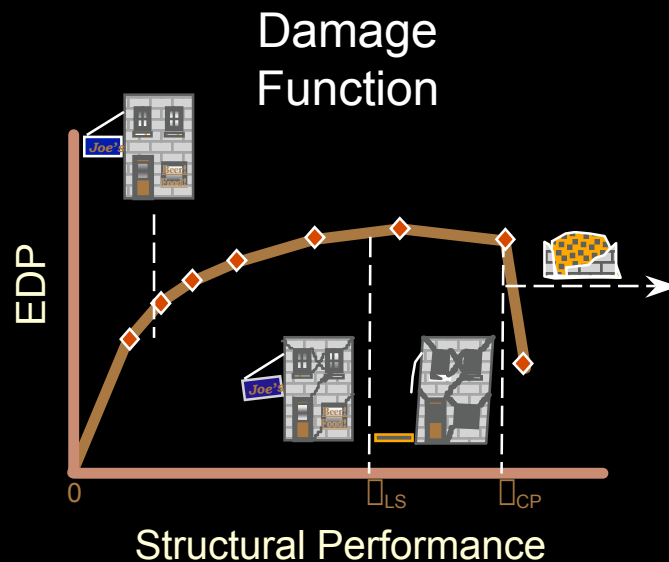
- Identification of most suitable intensity measures
  - Different for different types of structures?
  - Different for nonstructural components?
  - Methods of developing hazard functions for intensity measures
  - Quantification of uncertainties

# Needs – Analysis Procedures & Modeling Guidelines



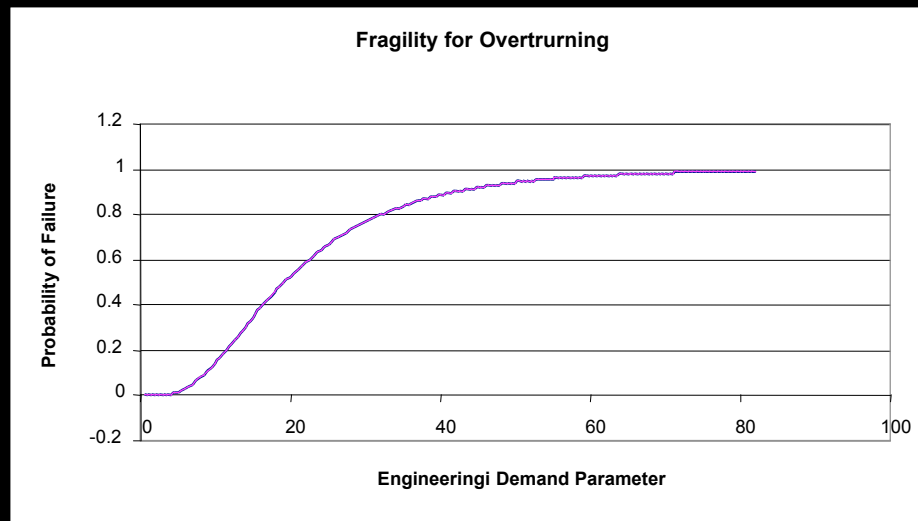
- Analytical methods that:
  - Are reliable:
    - unbiased
    - low variability
    - Consider soil-foundation-structure-component system
  - Are practical:
    - Can be implemented in design office

# Needs- Damage Functions



- Optimal demand parameters for characterizing damage:
  - Different structural elements
  - Global structural systems
- Acceptance criteria
  - Values of demand parameters that indicate different levels of damage

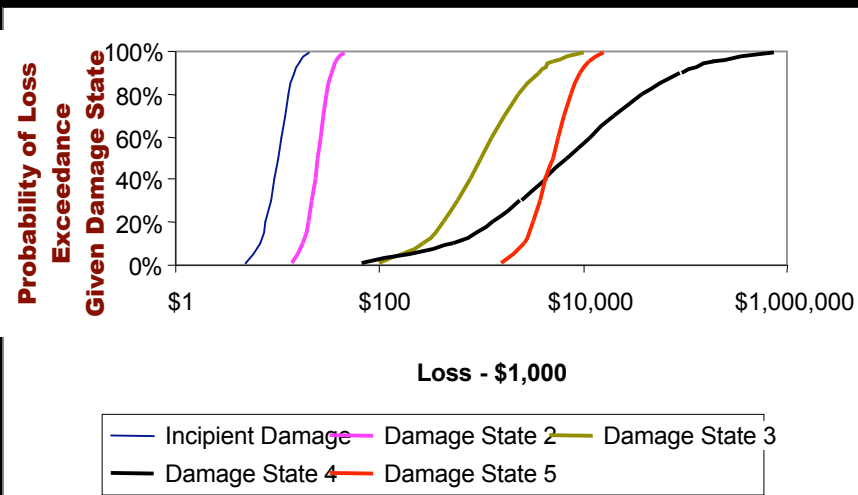
# Needs - Fragilities



- Procedures to convert structural analysis into structural fragilities
- Standardized fragilities for nonstructural components and systems



# Needs- Loss Functions



- Procedures for converting from damage to loss
- Standardized loss functions for various structural and nonstructural systems and damage states

# Needs – Engineering Office

- Simple procedures
- Straight forward explanation of process
- Software to aid implementation of procedures