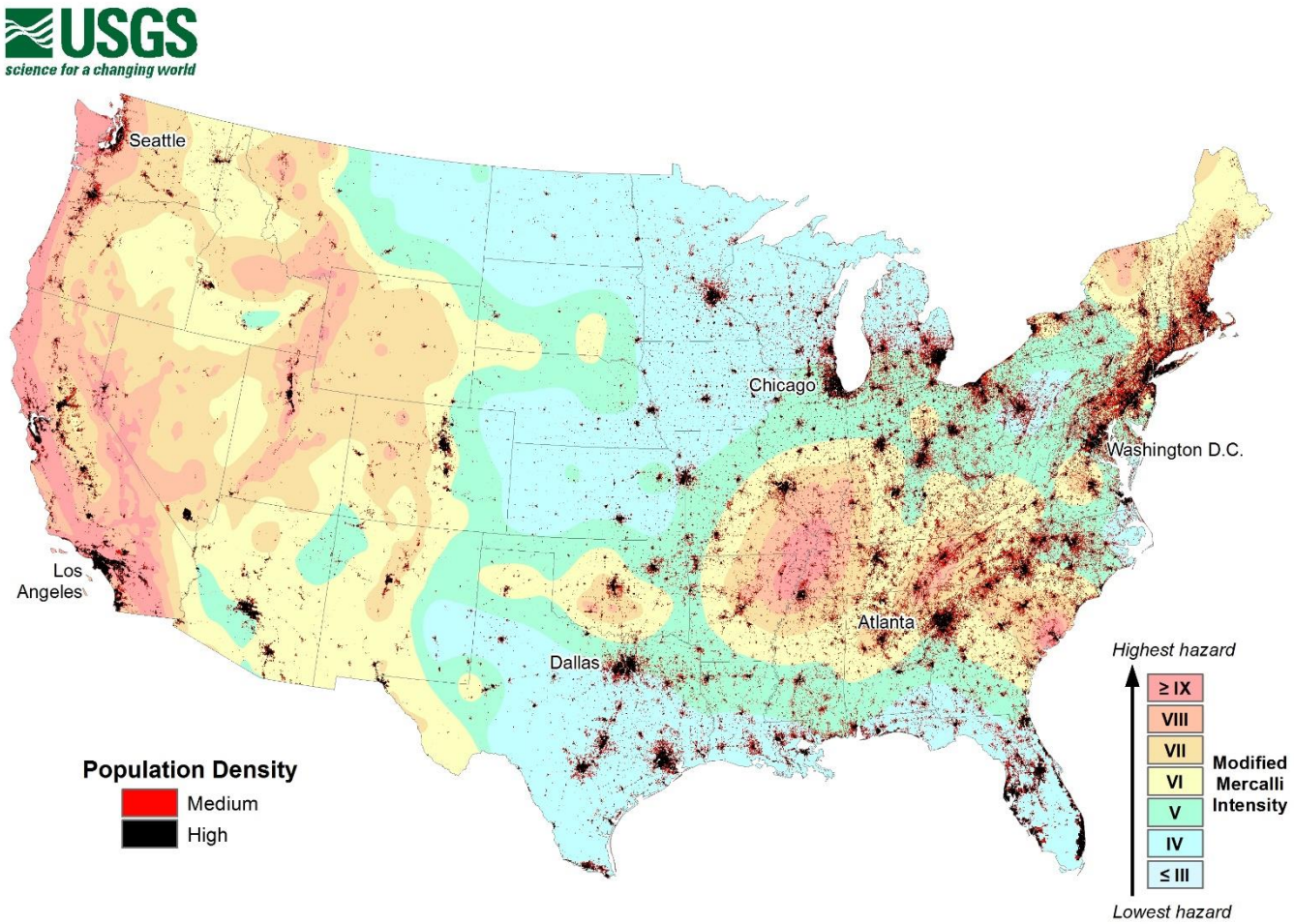
Resilient Design

Structural Perspective

OUTLINE

- Background
- Resilient Based Design
- State of the Art Methods
- Rating Systems

NATURAL HAZARDS



USGS map showing (1) the locations of major populations and (2) the intensity of potential earthquake ground shaking that has a 2% chance of occurring in 50 years

NATURAL HAZARDS

Christchurch - September 2010 - Design Basis EQ

Christchurch - February 2011 - Maximum Credible EQ

NATURAL HAZARDS

Christchurch -
Before & After 2/22
/2011

70% of buildings in downtown CBD are now demolished

Did building codes provide the performance expected ?

WE CAN DO BETTER

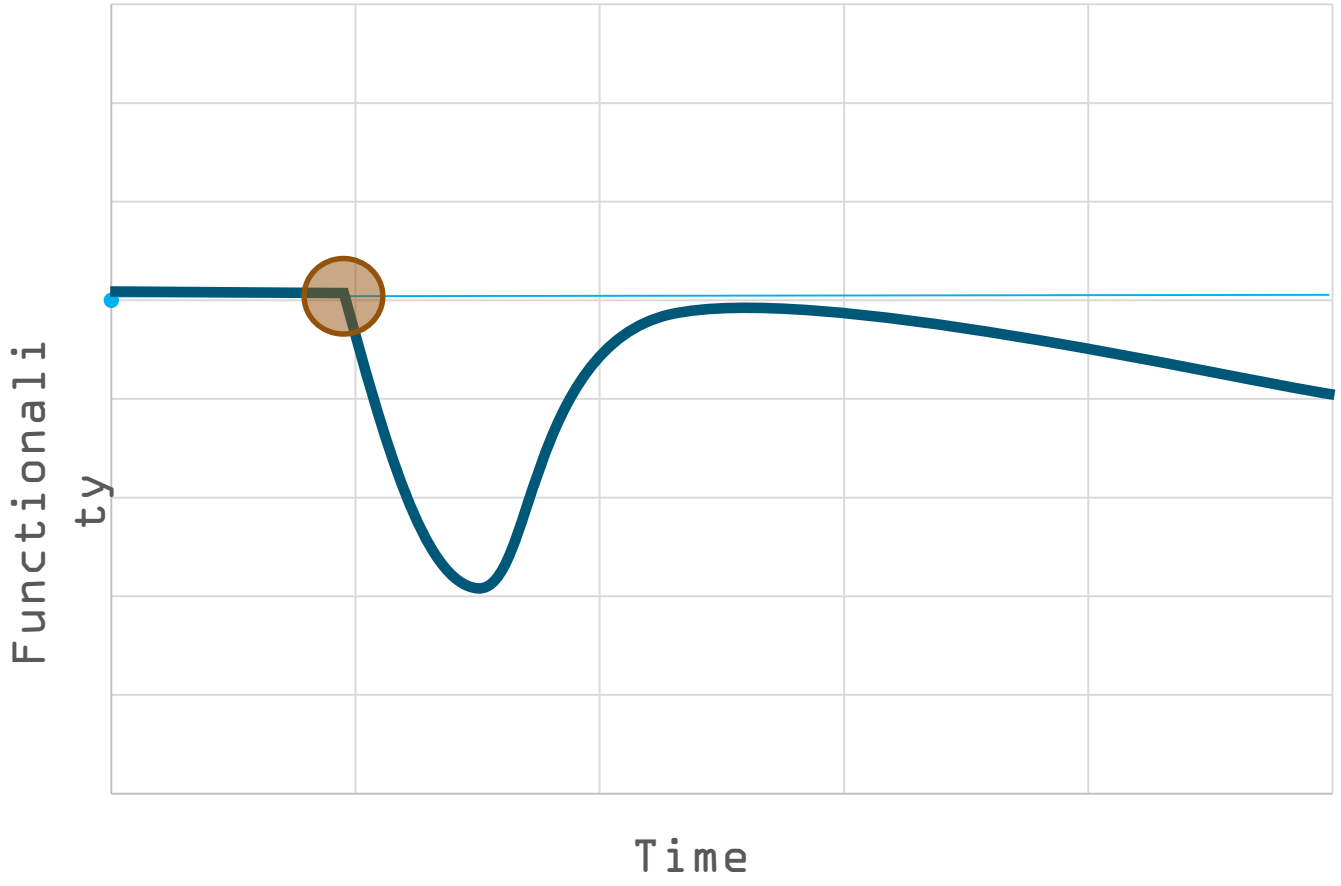
DEFINITION OF RESILIENCE

- The ability of a system to absorb change and maintain relationships between components.

- Prepare and plan for, absorb impacts of and recover from, or adapt to adverse hazards and threats.

- Community resilience is evident in its ability to absorb the impact of a hazard and continue to operate.

RESILIENCE DIAGRAM



RESILIENT BASED DESIGN

Building Code Based Design

Safety

Resilient Based Design

Safety

Time

Repair Cost

RESILIENT BASED DESIGN PROCESS

Dimensions	Objectives
Safety	Serious Injuries Unlikely
Time	Re-occupancy in X weeks Functional Recovery in X months
Repair Cost	<X% Replacement cost

Define Earthquake Hazard level at which this performance should be achieved.

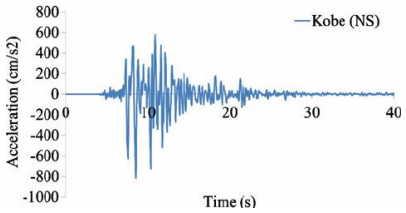
Define Acceptable Probability

STATE OF THE ART METHODS

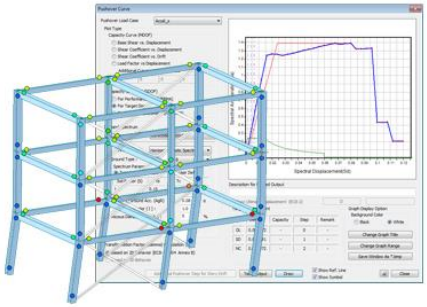
SEISMIC PERFORMANCE ASSESSMENT OF BUILDINGS - FEMA P-58 METHODOLOGY

- FEMA P-58 Methodology Developed by FEMA over Approximately 10years
- Probabilistic Performance Model of an individual building including the building inventory
- Performance characterized in probability of casualties, damage, repair cost and repair time
- Performance can be assessed for a particular earthquake scenario or intensity, or considering all earthquakes that could occur, and the likelihood of each, over a specified period of time.

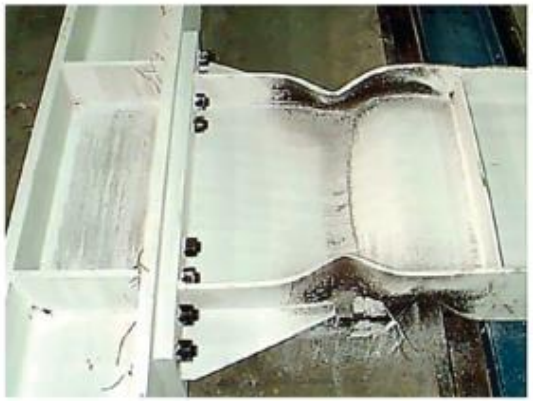
NEXT GENERATION PERFORMANCE BASED DESIGN METHODOLOGY



Ground Motion



Structural Response



Damage

Building Inventory

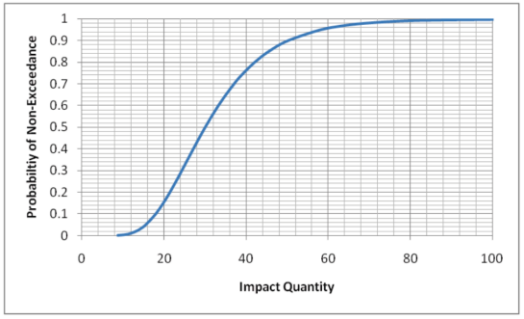


Figure 2-1 Hypothetical building performance function.

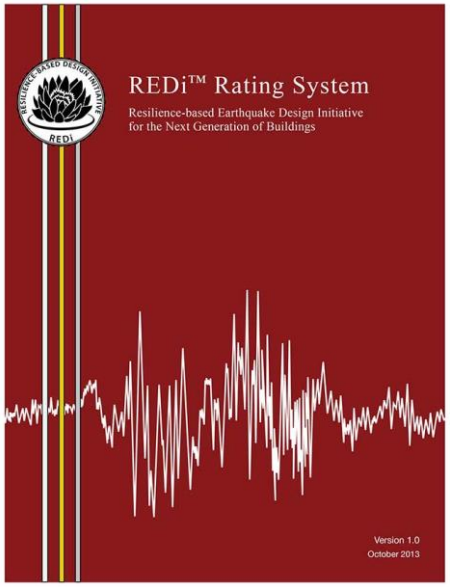
Probability Distributions

Safety Time

Repair Cost

Impact Predictions

RATING SYSTEMS



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https://youtu.be/0x9sZeNIit0

3 Dimensions and 5 Thresholds

Safety

5★	Injuries and blocking of exit paths unlikely
4★	Serious injuries unlikely
3★	Loss of life unlikely
2★	Loss of life possible in isolated locations
1★	Loss of life likely in the building

Damage

5★	Minimal damage (< 5%)
4★	Moderate damage (< 10%)
3★	Significant damage (< 20%)
2★	Substantial damage (< 40%)
1★	Severe damage (40%+)
NE	Not Evaluated

Recovery

5★	Immediately to days
4★	Within days to weeks
3★	Within weeks to months
2★	Within months to a year
1★	More than one year
NE	Not evaluated

EXAMPLES OF RESILIENT BASED DESIGN

- To date several buildings explicitly designed via Resilient Based Design objectives: one developer project and one Civic
- Civic project included resilient performance objectives as part of the RFP.
- Those projects and several more have reviewed first cost impacts and seen first cost increase variations from 1-10%.
- Notable differences in Resilient Based Design performance versus Code are in the Time & Repair Cost dimensions