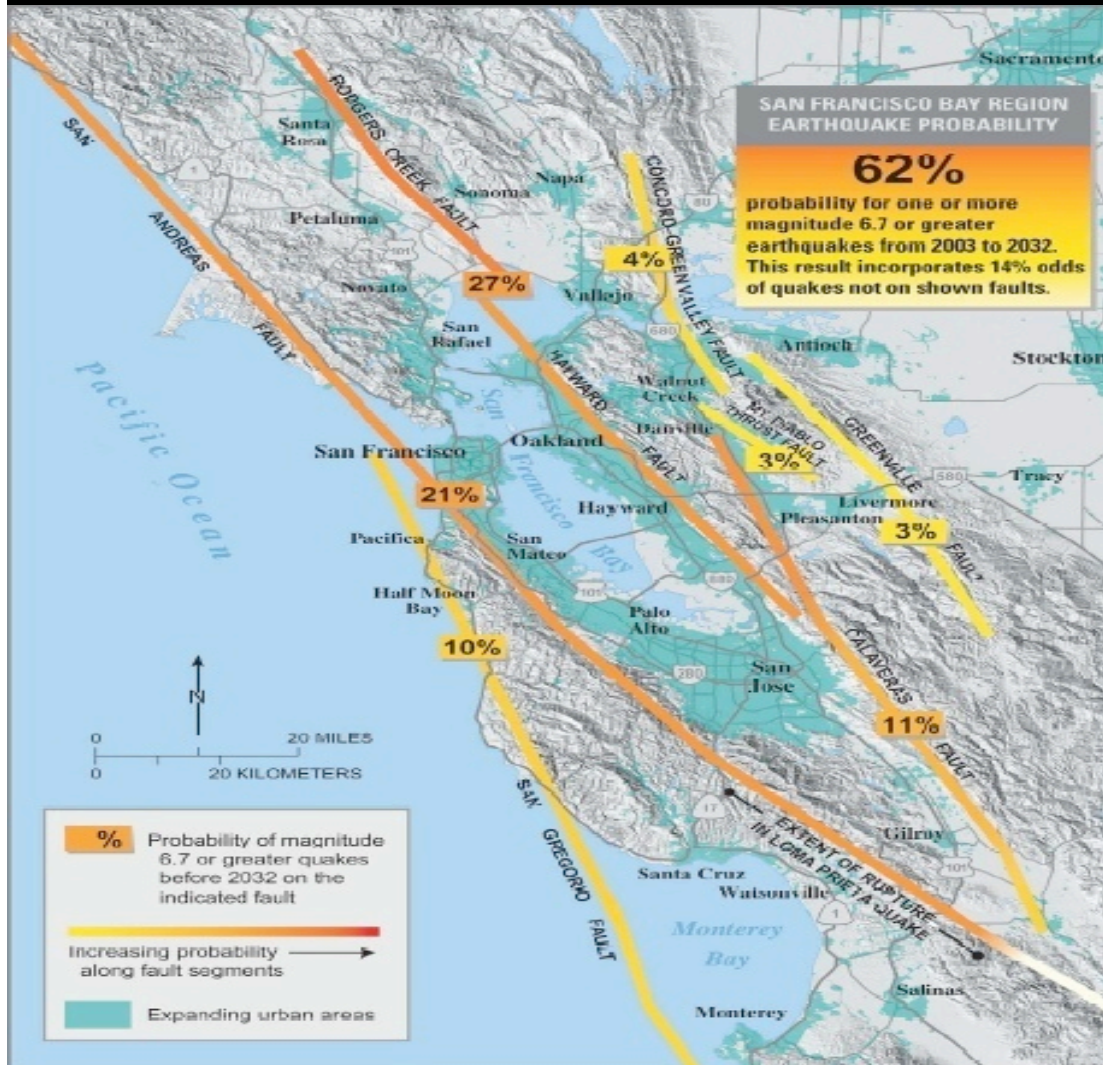


# Earthquake Hazards and Sustainability

# Bay Area Seismic Risk



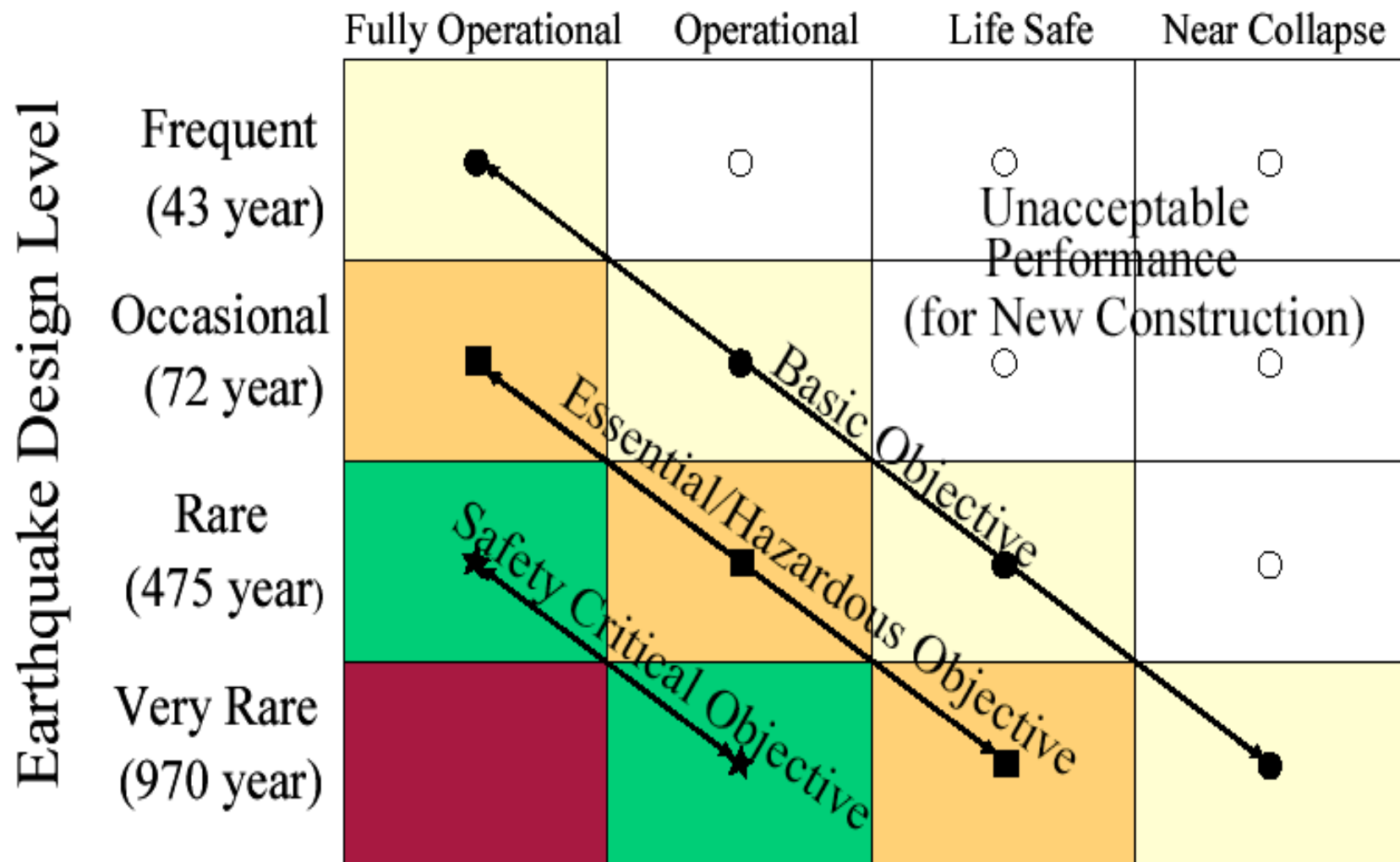
**62% probability of one or more Magnitude 6.7 EQ's in next 30 years**

[www.usgs.org](http://www.usgs.org)

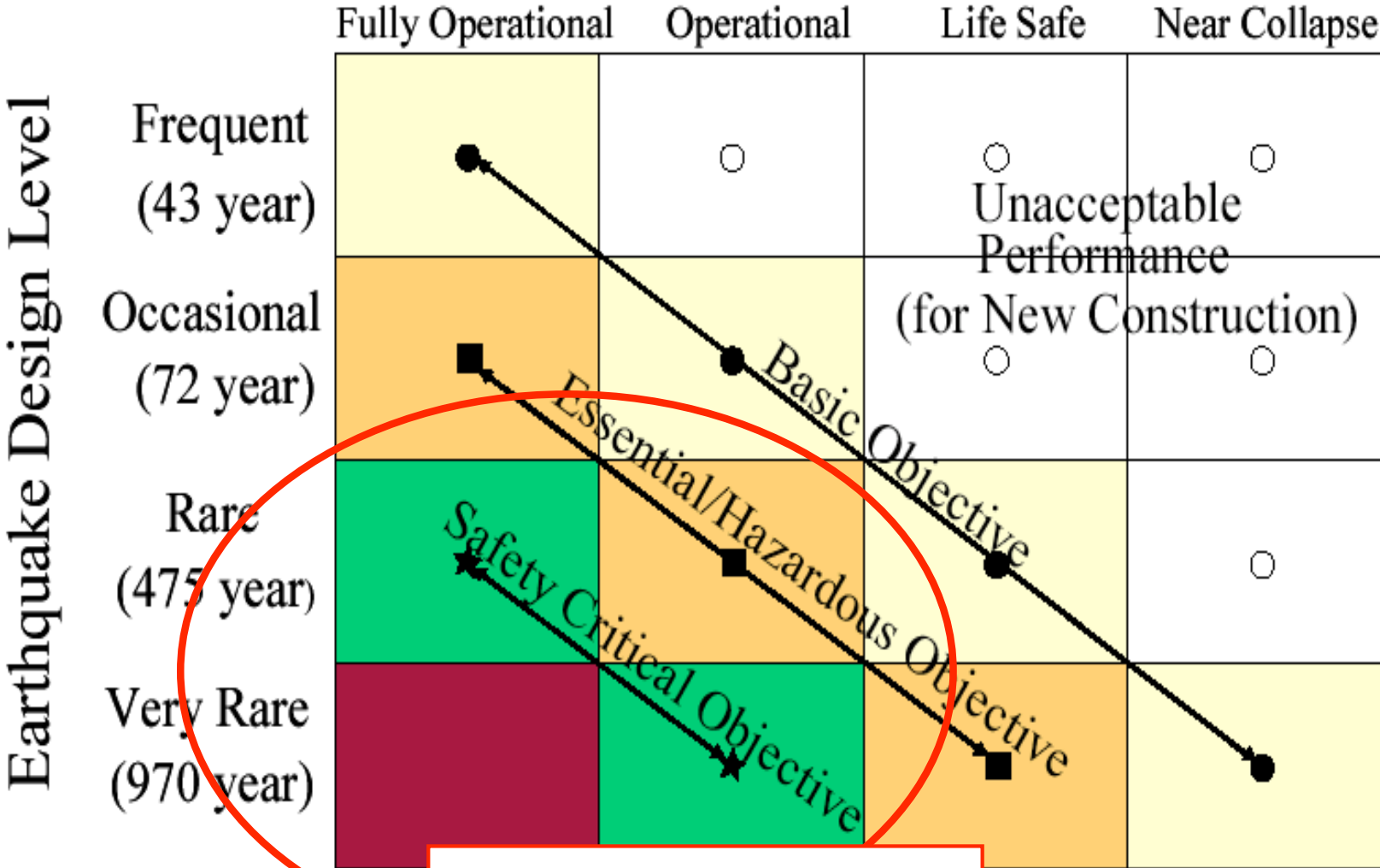
# Performance Based Design (PBD)

- **Probability of loss**
- **Structural performance objectives**
- **Non-structural performance objectives**

# Performance Based Engineering

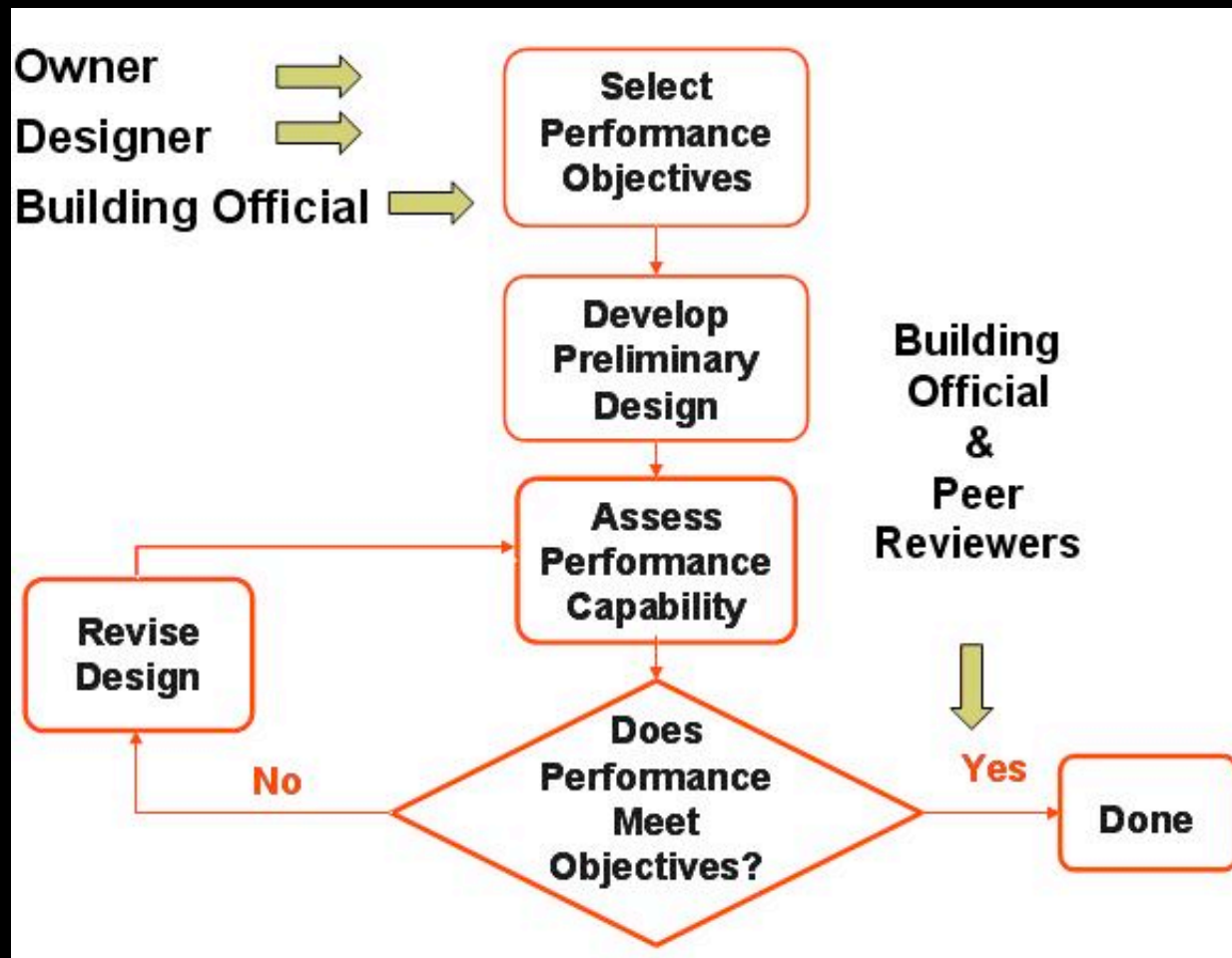


# Performance Based Engineering



Advanced Seismic Protection Techniques

# Performance Based Design



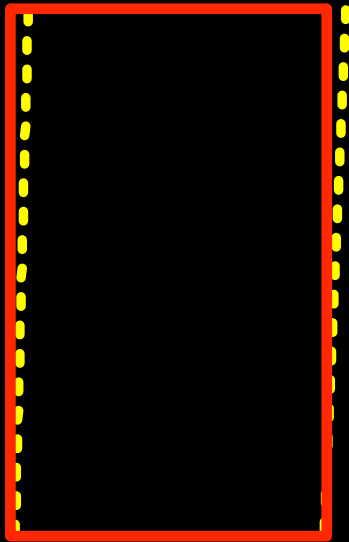
FEMA 445

# Performance Based Design

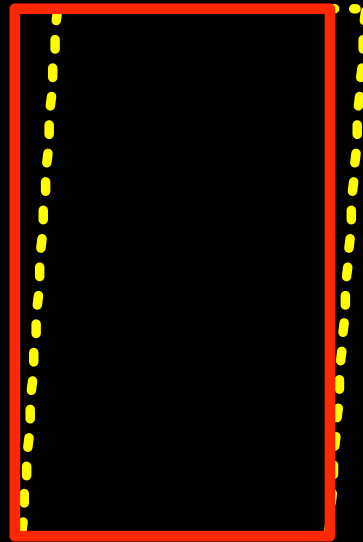
**Seismic Performance → more than just structure!**

- **Nonstructural elements**
  - Mechanical, electrical, plumbing systems
  - Architectural elements
- **Building contents: furniture, computers, business documents**

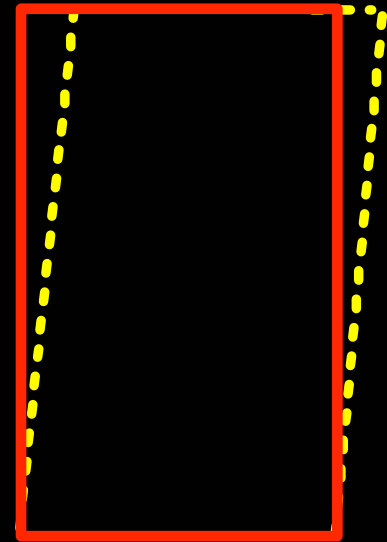
# Embodied Energy and Non-Structural Elements



1% Drift  
Partitions with Doors  
Beyond Repair



1.5% Drift  
Solid Partitions  
Beyond Repair



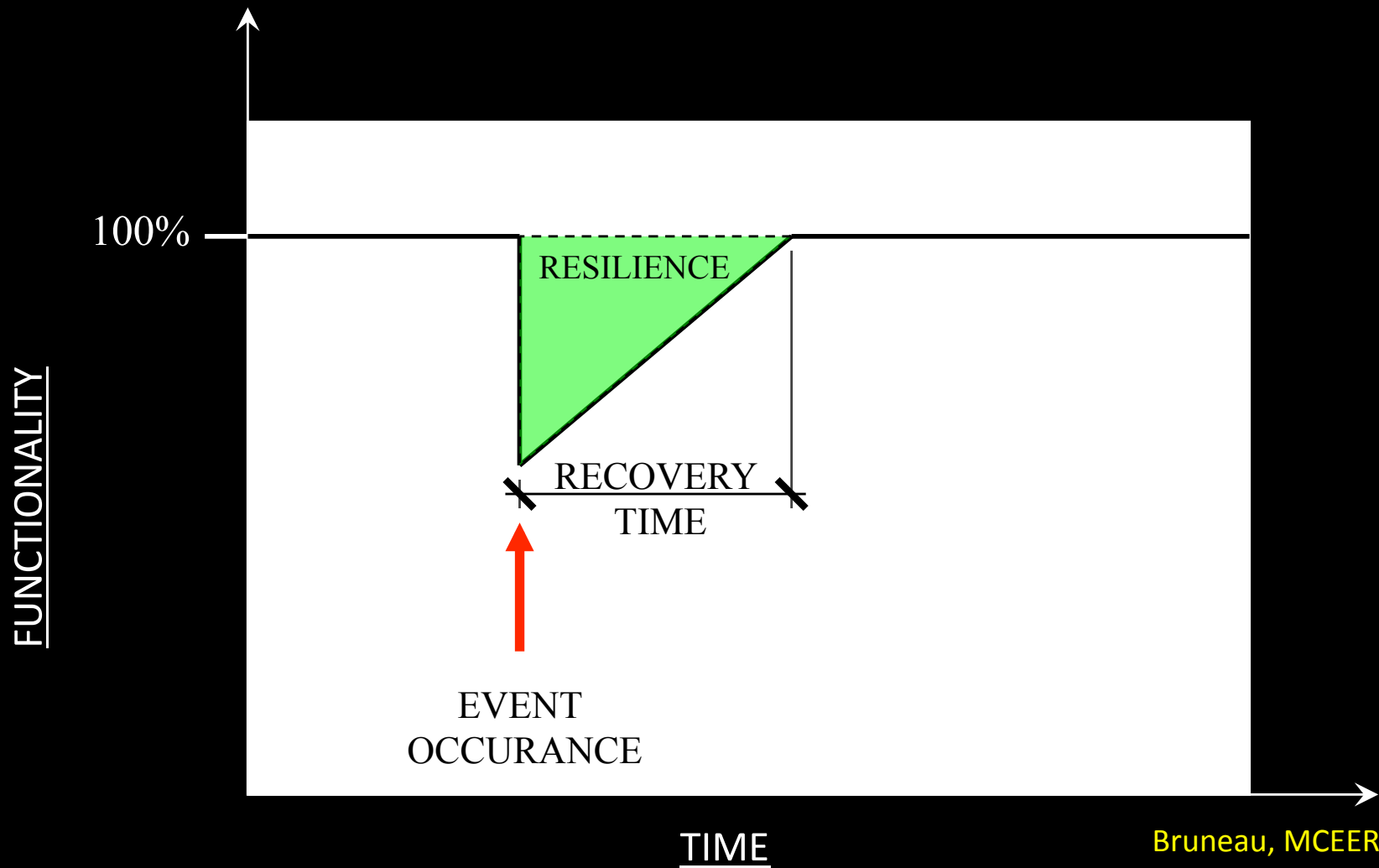
2.5% Drift  
Building Code  
Limit



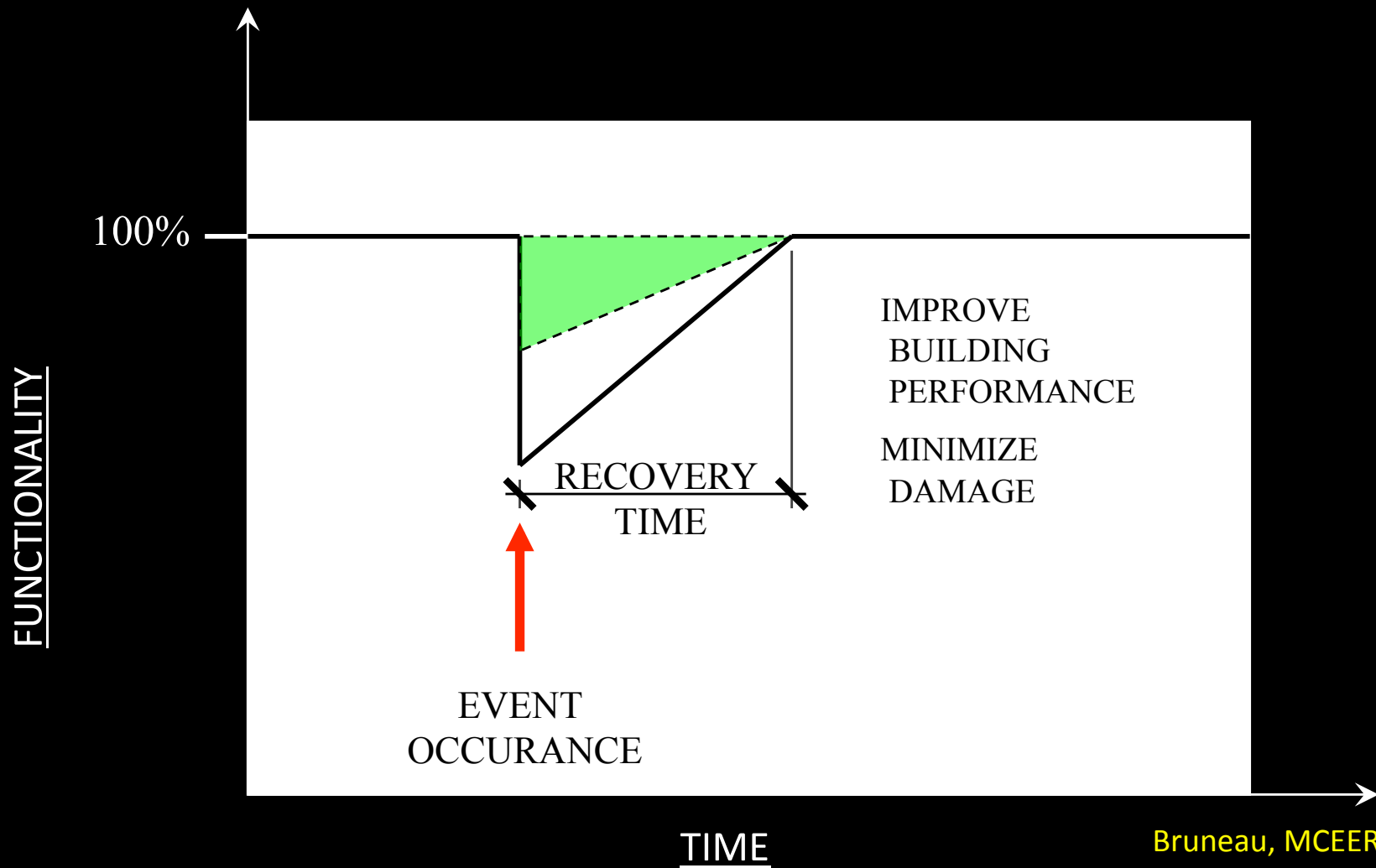
# Disaster Resilience

**Building's ability to recover from a  
natural disaster**

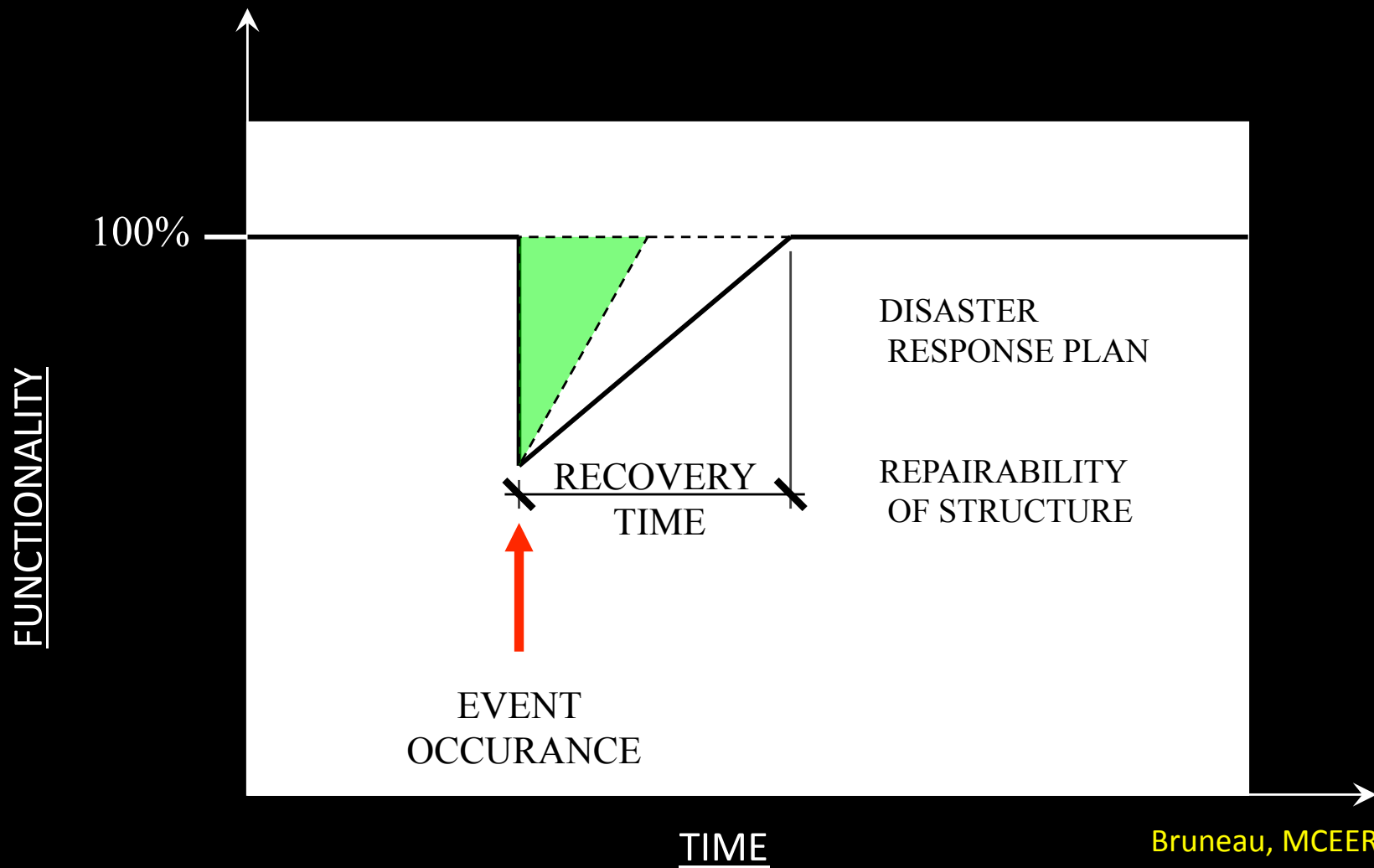
# Disaster Resilience



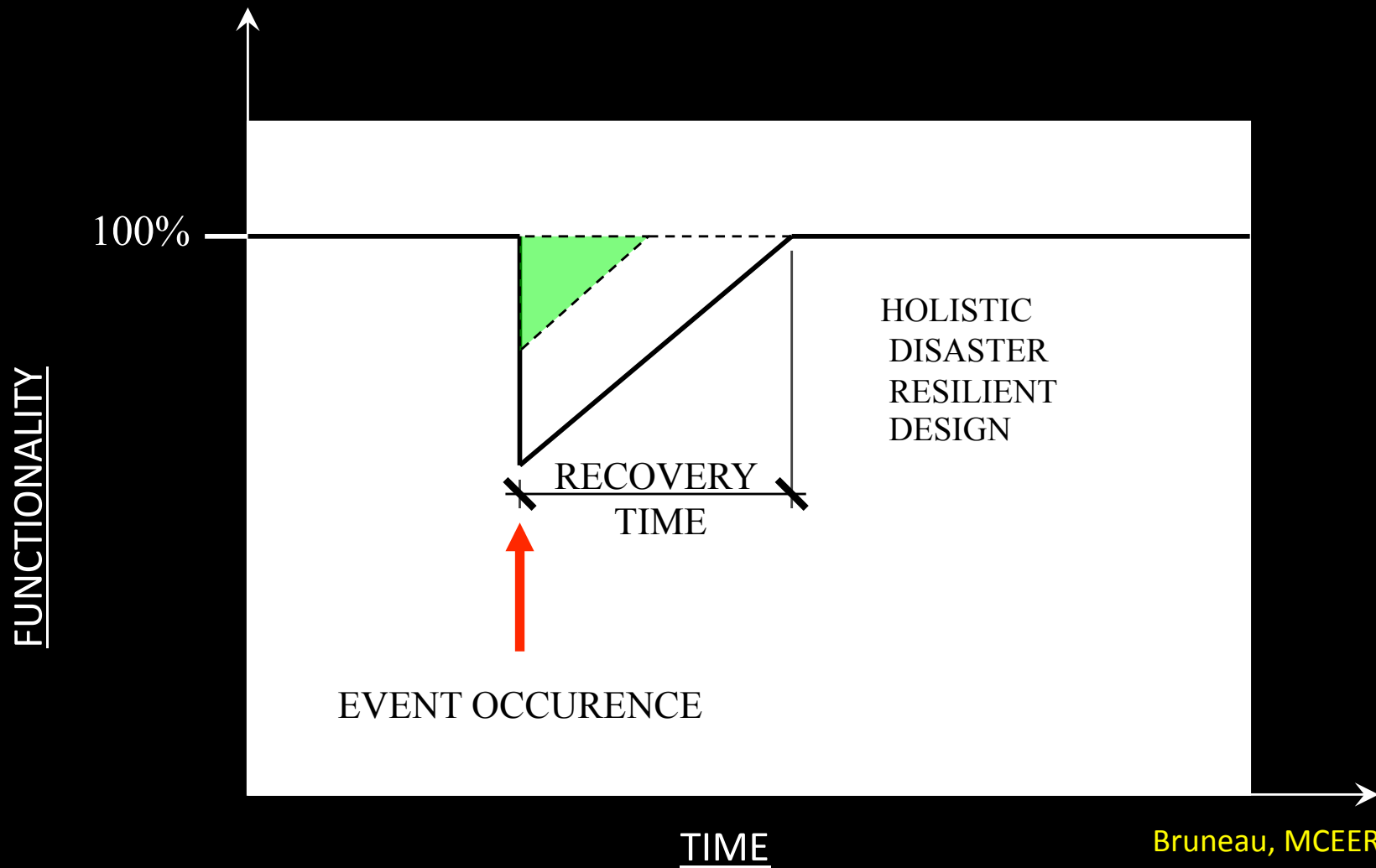
# Disaster Resilience



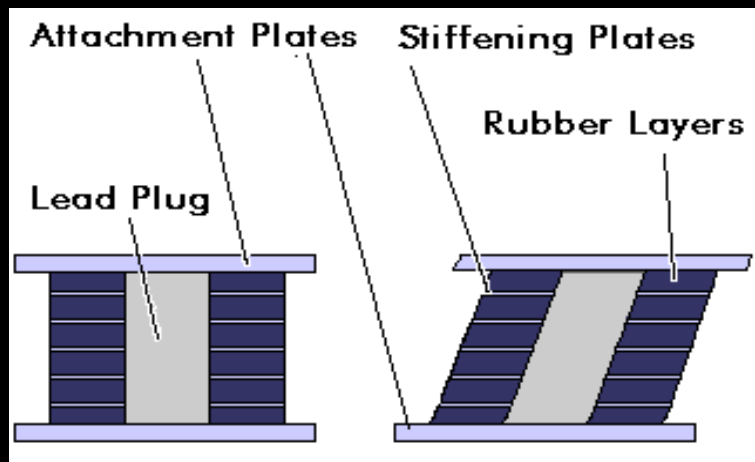
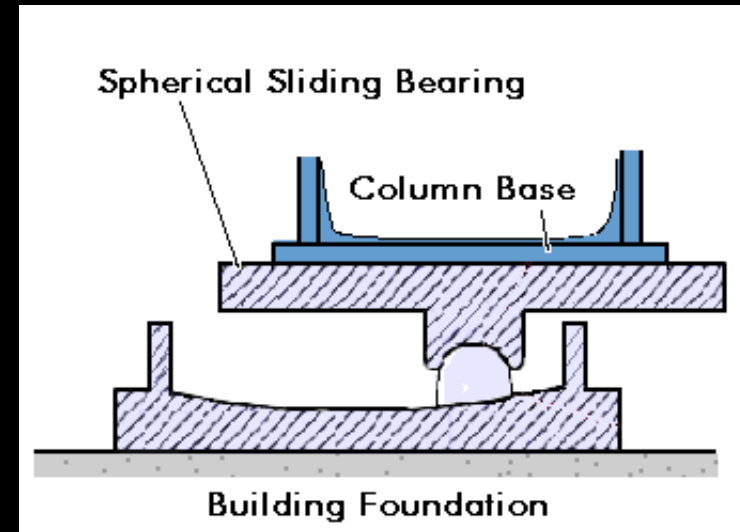
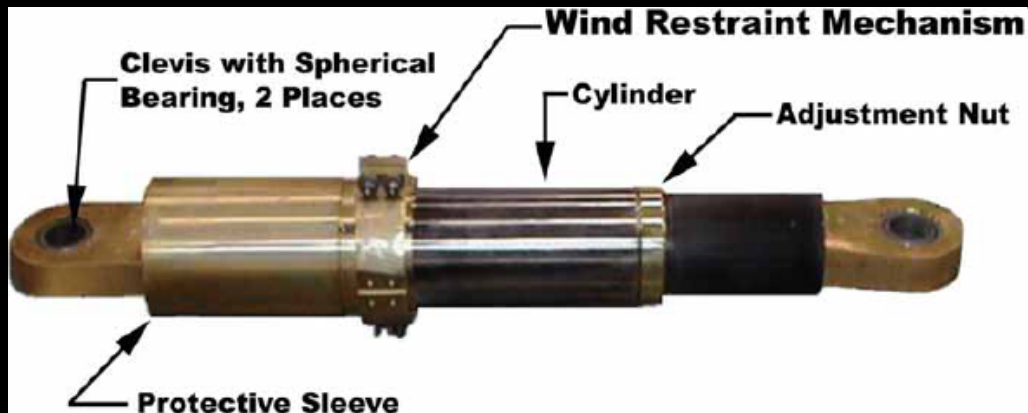
# Disaster Resilience



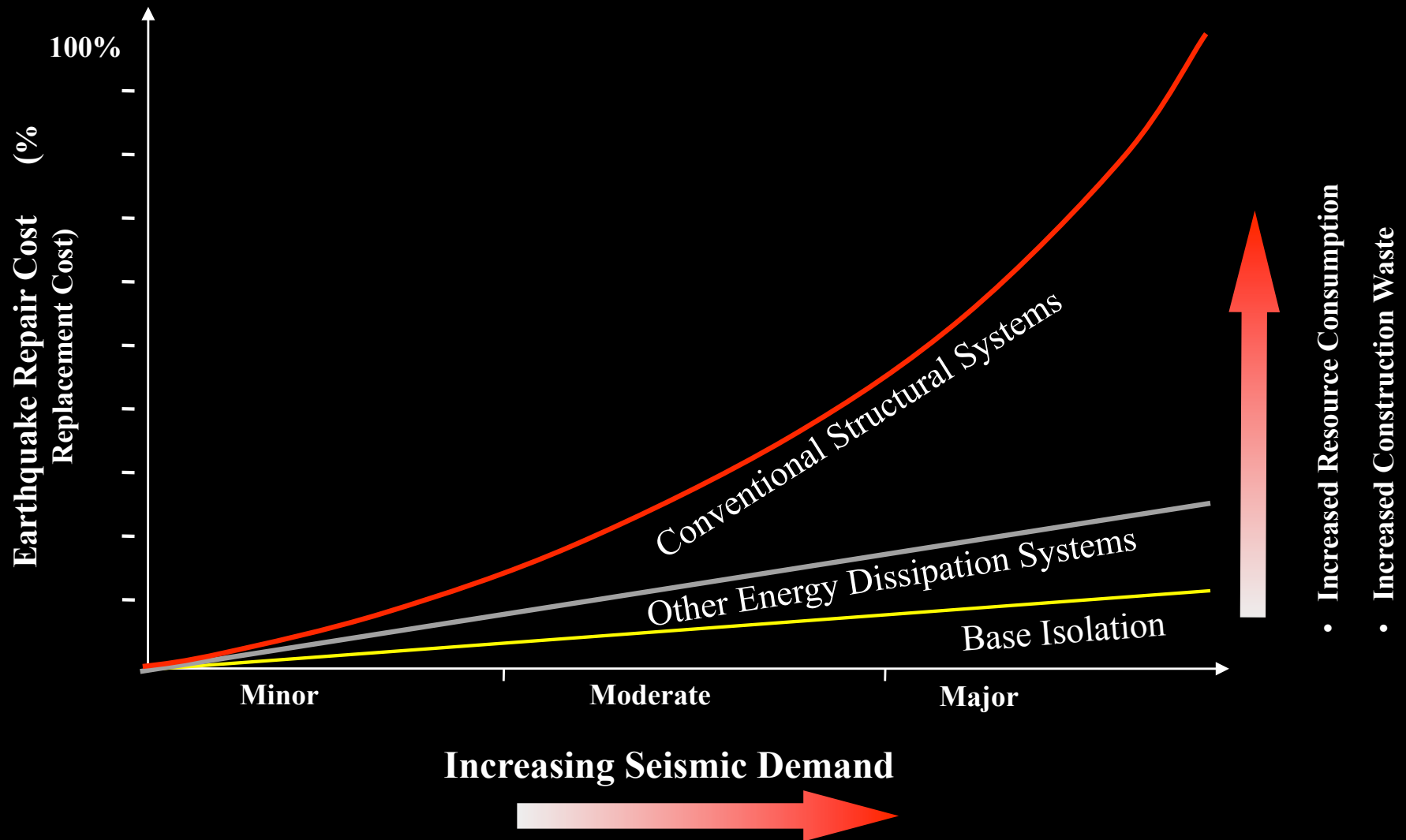
# Disaster Resilience



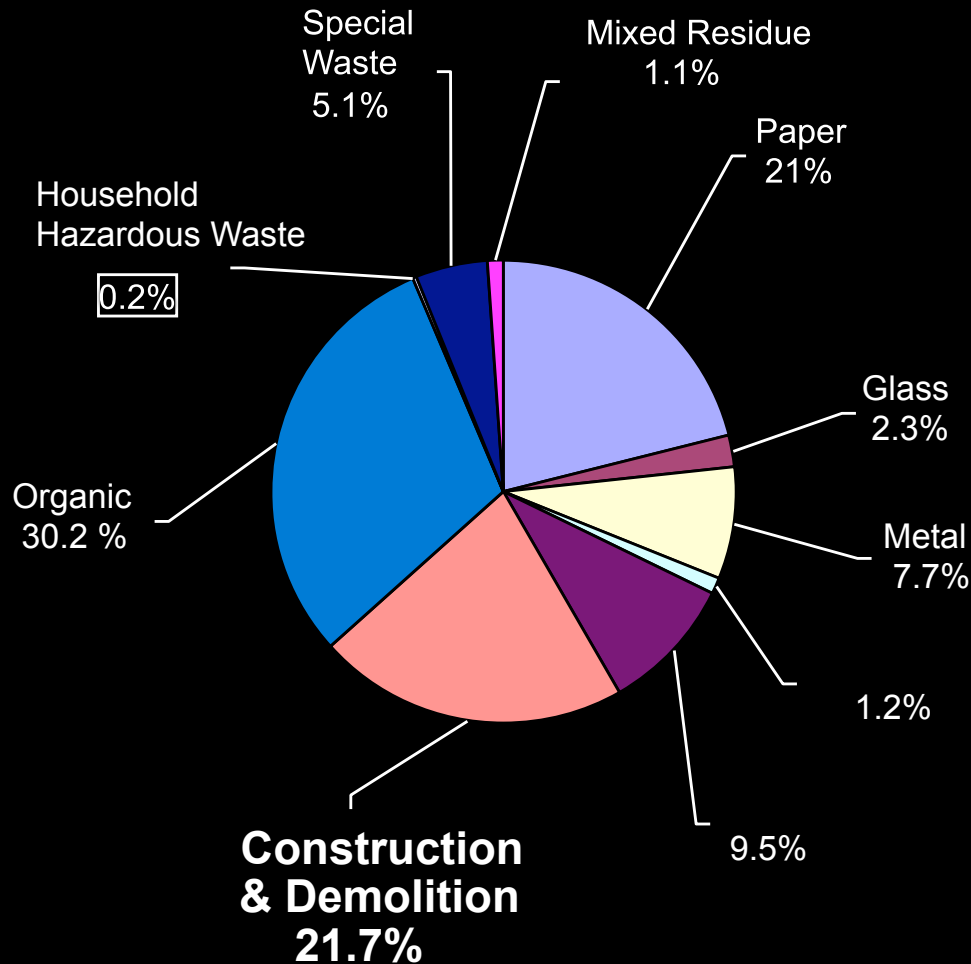
# Improving Performance through Advanced Systems



# Improving Performance through Advanced Systems

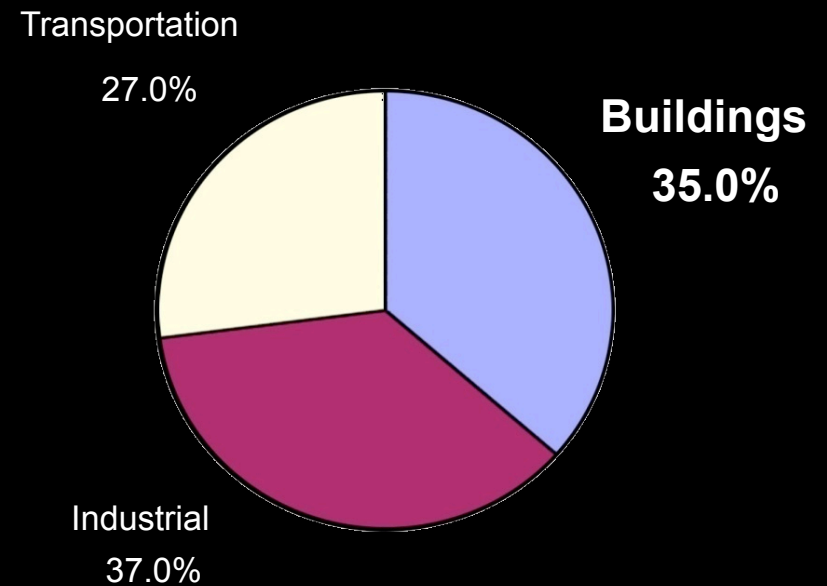


# Environmental Impact



California's Overall Waste Stream 2004

CIWMB



Total Energy Use in US in 1998

Battle & Burns

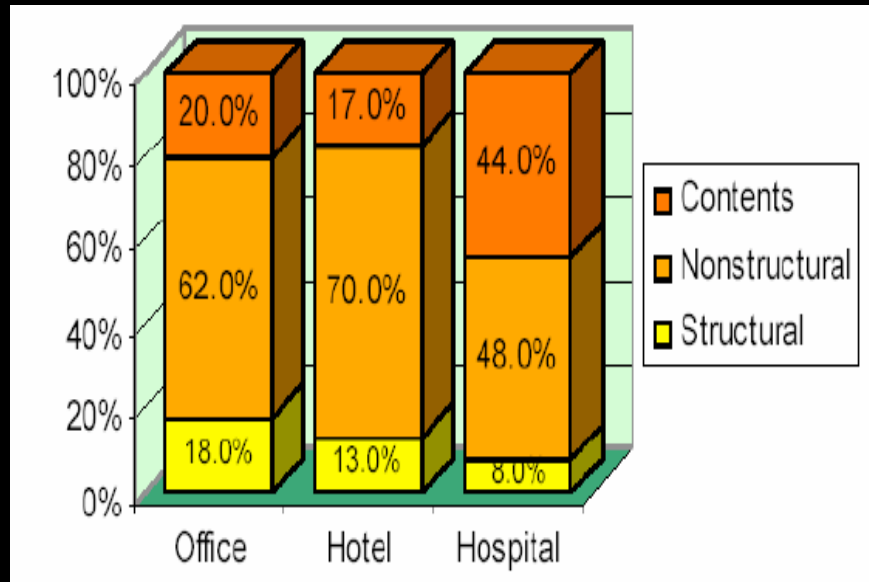


# Embodied Energy

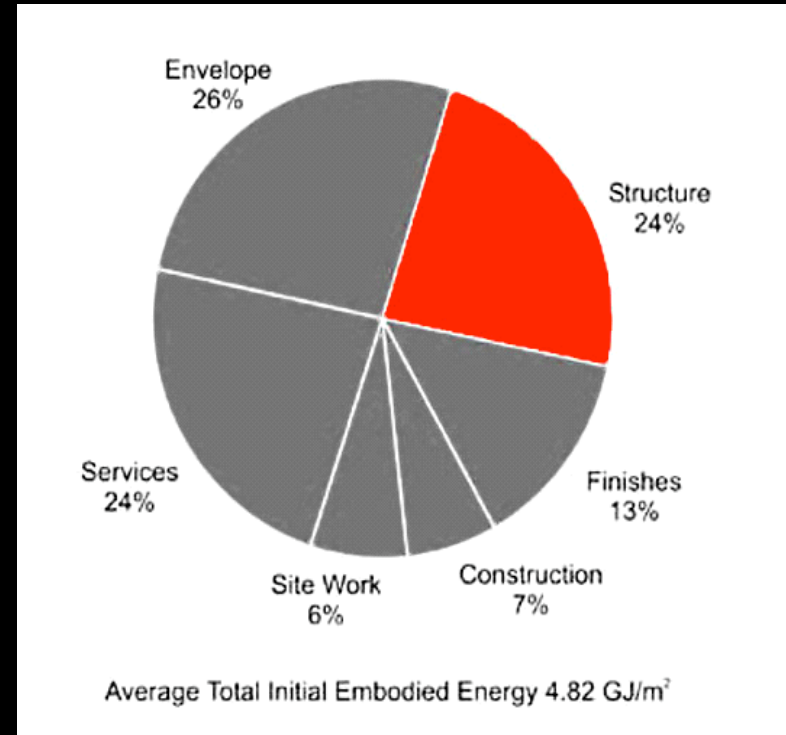
- Includes...
  - Raw Materials
  - Processing of Materials
  - Transportation
  - Construction
  - Furnishing
  - Waste



# Embodied Energy



**Distribution of Construction Costs**  
Taghavi and Miranda



**Athena Institute**

# Embodied Energy

**Total Building Energy =**

Embodied Energy + Operational Energy

**Annualized Carbon Footprint =**

Embodied Energy ÷ Building Life + Operational Energy

# A Major Earthquake's Impact on Housing Sustainability

- “Here Today – Here Tomorrow: Earthquake Safety for Soft-Story Buildings” by ATC
- Focus on Multi-Unit soft story wood framed buildings
- 4,400 buildings in San Francisco of this type
- Estimate 1200 - 2400 will be “Red Tagged”
- Estimate 300 - 850 will Collapse

# Soft Story Collapse





# Impact on Residents

- 50,000 people will be displaced
- Slow to Rebuild
- Loss of Neighborhood Character
- Loss of affordable housing



San Francisco, 1906



Izmit, Turkey 1999



Gaoyuan Village, China 2008

# Impact on the Environment

- 1 Building ~ 940 Cars ~ 4,150 Tons of CO<sub>2</sub>
- Total Red Tagged buildings account for 2.27 Million Cars or 10 Million tons of CO<sub>2</sub>



=



# Impact on the Economy

- Cost to Retrofit = \$3 - \$12 per/ft<sup>2</sup>
- Cost to Rebuild = \$200 per/ft<sup>2</sup>
- Cost to Rebuild = 20 times Cost to Retrofit



=





# Sustainable Benefits of Retrofit

- Preventing 10 Million Tons of CO2 from Landfill
- Minimizing Disruption to 50,000 Residents
- Protecting our Initial Economic Investment
- Preserving our Communities

# Benefits of Improved Seismic Performance



Reduces Repair Cost and Repair Time



Reduces Impact on Residents and Community



Minimizes Environmental Impact



Enhances Sustainable Community

# Questions?