Basic Concepts: Performance-based Earthquake Engineering

Seismic Performance -- Some questions to consider

- ✓ What are our goals?
- ✓ What are suitable frameworks for expressing performance goals
  - Conceptual -- from the owners/clients perspective
  - Quantitative --from the engineers perspective
- ✓ Performance Metrics vs. Engineering Response Parameters
- ✓ Nonlinear response - Is it a desirable feature or a problem to overcome?
- ✓ Having set our goals, how do we achieve them?

Goals: Our Performance Expectations?

Different approaches

- Current codes - What are their stated objectives?
- Ideal situation - A simple limit states framework for design.
- Current directions - Vision 2000 (SEAOC), SAC LRFD approach, etc.
- Future directions - reliability-based approaches, PEER performance-based evaluation strategy, FEMA/ATC-58

References

References: Performance-Based Design Codes

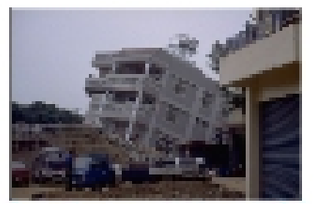
- Hamburger, R.O., Performance-Based Analysis and Design Procedure for Moment Resisting Steel Frames, Background Document, SAC Steel Project, Sept. 1998.
- SEAOC, Vision 2000: Performance Based Seismic Engineering of Buildings, San Francisco, April 1995.
- Recommended Seismic Design Criteria for New Steel Moment-Frame Buildings, *FEMA 350, Federal Emergency Management Agency, Washington DC, July 2000*
- FEMA, Guidelines for Seismic Rehabilitation of Buildings, Vol. 1: Guidelines, FEMA 356, Washington DC, 2002 (formerly FEMA 273).
- Earthquake Engineering Research Center, Performance-based Seismic Design of Buildings: An Action Plan , U.C., Berkeley, 1995.
- FEMA/EERI, Action Plan for Performance -Based Seismic Design, FEMA 349, Washington DC, 2000.
- ATC, Development of Performance-based Earthquake Design Guidelines, ATC-58, Redwood City, 2002.

Current Model Codes

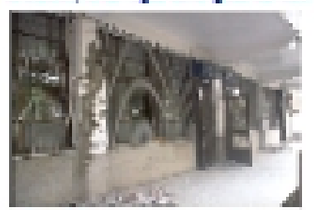
CBC (UBC), IBC, ASCE-7

- Stated purpose:
  - ✓Provide minimum provisions for design and construction of structures to resist effects of seismic ground motions
  - ✓"...to safeguard against major structural failures and loss of life, not to limit damage or maintain function."

(UBC, 1997 ed., Section 1626)



Structurally undamaged building across fault



Shear failures in short "captive" columns

SEAOC "Blue Book" Recommendations

Commentary states:

Three Tiers

	Earthquake Intensity	Frequency of Occurrence	Desired Performance
1	Minor	Several times during service life	No damage to structure or nonstructural contents
2	Moderate	One or more times during service life	Limited damage to nonstructural components and no significant damage to structure
3	Major (Catastrophic) (10% exceedance in 50 years)	Rare and unusual event as large as any experienced in vicinity of site.	No collapse of structure or other damage that would create a life safety hazard.

(After Lateral Force Recommendations and Commentary, SEAOC)

However, stipulated goals in codes are ambiguous...

- Definitions are non-quantitative (e.g., *limited* damage, one *or more* times, etc.)
- Three tiers, but...
  - ✓ Only one design earthquake
  - ✓ Provisions not specifically associated with any particular performance level.
- Approach leads to wide variation in interpretation and performance.

Vision 2000 - Trends toward Performance-Based Seismic Engineering of Buildings

Seminal Document - some powerful new concepts

- The definitions of performance states developed are:
  - ✓ incorporated in the appendices of the SEAOC "Recommended Lateral Force Requirements and Commentary"
  - ✓ refined by other groups in later documents
- Focuses on:
  - ✓ defining what constitutes a frequent, rare or very rare earthquake, and
  - ✓ describing in detail what are the performance states that one wants for different types of events and structures.

"Vision 2000" Approach is a major conceptual advance

Relationship developed between:

- ✓ Performance objective
- ✓ Type of facility
- ✓ Probability of earthquake

and

Response parameters related to each performance objective.

- ✓ Specific demand parameters identified, and
- ✓ Initial acceptance criteria are established.

Performance objective increases (i.e., less damage):

- ✓ for a high probability earthquake (one that may occur several times during the life of a structure), or
- ✓ for an important structure or dangerous occupancy (i.e., a hospital or dynamite plant)

Conversely, more damage is acceptable:

- ✓ for a rare, severe earthquake,
- ✓ for less critical or temporary facilities.

Vision 2000 - Performance States

- **Fully operational** — Continuous service. Negligible structural and non-structural damage.
- **Operational** — Most operations and functions can resume immediately. Structure safe for occupancy. Essential operations protected, non-essential operations disrupted. Repair required to restore some non-essential services. Damage is light.
- **Life Safe** — Damage is moderate, but structure remains stable. Selected building systems, features or contents may be protected from damage. Life safety is generally protected. Building may be evacuated following earthquake. Repair possible, but may be economically impractical.
- **Near Collapse** — Damage severe, but structural collapse prevented. Non-structural elements may fall.

Occupancy or Use of Building Considered

Three occupancy types considered in Vision 2000.

- Safety Critical Facilities:
  - ✓ Large quantities of hazardous materials (toxins, radioactive materials, explosives) with significant external effects of damage to building.
- Essential/Hazardous Facilities
  - ✓ Critical post-earthquake facilities (hospitals, communications centers, police, fire stations, etc.)
  - ✓ Hazardous materials with limited impact outside of immediate vicinity of building. (Refineries, etc.)
- Basic Facilities
  - ✓ All other structures.

One can argue with or adapt these definitions.

Quantitative Indexing of Earthquake

The earthquake intensity is now described quantitatively in probabilistic terms for Vision 2000.

Earthquake Classification	Recurrence Interval	Probability of Occurrence
Frequent	43 years	50% in 30 years
Occasional	72 years	50% in 50 years
Rare	475 years	10% in 50 years
Very Rare	970 years*	10% in 100 years

* need not exceed mean + 1 standard deviation for the maximum deterministic event.

Schematic Relation Between Performance Objective and Earthquake Probability