Background of Seismic Codes and Performance Expectations

PEER Tall Buildings Initiative—Task 2
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Background of Building Codes

- 1666 London fire resulted in first comprehensive building code and set precedent for government enforced codes
- Each country has its own somewhat unique history of how authority for building codes evolved.
- Important principal of U.S. Constitution is delegation of *police power* to states:
  - Police power is the authority to regulate for the health, safety, and general welfare of its citizens.
  - Typical Building Code *Purpose* statement:
    - The purpose of this code is to provide minimum standards to safeguard life or limb, health, property, and public welfare by regulating and controlling the design, construction, quality of materials, use and occupancy, location and maintenance of all buildings and structures…

Background of Seismic Codes

- 1755 Lisbon devastating earthquake resulted in prescriptive rules for building certain kinds of buildings common in the area
- Events in Messina, Italy (1911), and Kanto (Tokyo) Japan (19023) led to guidelines for engineers to design buildings for horizontal forces of about 10% of the weight of the building.
- 1906 San Francisco, interestingly, produced little or no code development in the US.
- 1925 San Barbara convinces critical mass in California on the need for seismic requirements
- 1927 First seismic regulations as voluntary appendix in 1927 Uniform Building Code
- 1933 Long Beach results in CA legislature passing the Field Act (for schools) and the Riley Act (for all buildings).
- Code under constant evolution since 1927, with changes often instigated by earthquakes in CA.

Charleston, 1886

San Francisco, 1906

Santa Barbara, 1925

Long Beach, 1933

Purpose of First Codes Clear

- Prevent collapse
- Prevent heavy materials falling to street
- Size or rareness of earthquake not specified—and probably not understood. References are to "earthquake loading"

Introduction to 1927 UBC Lateral Bracing Appendix

"The design of buildings for earthquake shocks is a moot question but the following provisions will provide adequate additional strength when applied in the design of buildings or structures."

Enduring Performance Intent by Structural Engineers Association of California*

Recommended Lateral Force Requirements and Commentary, SEAOC, 1968

"The SEAOC Code is intended to provide criteria to fulfill the purposes of building codes generally. More specifically with regard to earthquakes, structures designed in conformance with the provisions and principles set forth therein should be able to:

1. Resist minor earthquakes without damage;
2. Resist moderate earthquakes without structural damage, but with some nonstructural damage;
3. Resist major earthquakes, of the intensity of severity of the strongest experienced in California, without collapse, but with some structural as well as nonstructural damage.

In most structures, it is expected that structural damage, even in a major earthquake, could be limited to repairable damage. This, however, depends on a number of factors…"

* Interview Issue

Current Evolution

- "Earthquake" changed to "ground motion":
- Item 3 word-smithed: "Resist a major level of earthquake ground motion—of an intensity equal to the strongest earthquake, either experienced or forecast, for the building site—without collapse, but possibly with some structural as well as nonstructural damage."
- "…damage limited to repairable level for most structures… <u>In some instances, damage may not be economically repairable</u>."
- "No Guarantee" paragraph added:
  "…While damage to the primary structural system may be either negligible or significant, repairable or virtually irrepairable, it is reasonable to expect that a well planned and constructed structure will not collapse in a major earthquake. The protection of life is reasonable provided, but not with complete assurance."

No Zero Risk*

First explicit discussion of actual risks for building construction appeared in commentary of ATC 3, which was intended to develop more rational and scientific seismic design provisions. (Tentative Provisions for the Development of Seismic Regulations for Buildings, ATC, 1978)

“It is not possible by means of a building code to provide a guarantee that buildings will not fail in some way that will endanger people as a result of an earthquake. While a code cannot ensure the absolute safety of buildings, it may be desirable that it should not do so as the resources to construct buildings are limited. Society must decide how it will allocate the available resources among the various ways in which it desires to protect life safety. One way or another, the anticipated benefits of various life protecting programs must be weighed against the cost of implementing such programs.”

ATC 3 suggested that this risk is primarily due to uncertainty in the characteristics of the ground motion…

Now, we might also add a healthy dose of uncertainty due to our inability to write code provisions that will produce a narrow band of seismic performance for each of the many combinations of structural systems and building configurations built in the US.

More… No Zero Risk

- More from ATC 3: "If the design ground motion were to occur, there might be life-threatening damage in 1 to 2 percent of buildings designed in accordance with the provisions. If ground motions two or three times as strong as the design ground motions were to occur, the percentage of buildings with life-threatening damage might rise to about 10 to 50 percent respectively."
- Current research that studied only a couple of structural types concluded that for ground motions 1.5 times as great as our design ground motions, about 10% of code designed buildings may fail. (ATC 63, in progress).
- This led to the interview scenarios, describing <u>normal code buildings</u>

Hypothetical Performance	Expected No. of Bldgs in each Structural Damage State				
	None/Slight	Moderate	Extensive	Complete	Collapse
Level A	20	15	4	1	0
Level B	19	9	7	4	1
Level C	12	6	9	9	4

Definition of ground motions for performance objectives*

- Initially: “earthquake shaking”
- SEAOC: minor, moderate, major earthquake; later ground motion
- SEAOC/UBC: Design Basis Event (DBE): 10% chance of exceedance in 50 years or 475 year return period
  - Commonly called the 500 year event
  - Sometimes called the Rare event
- 1997 National Mapping of Maximum Considered Earthquake Ground Motions (MCE)
  - Sometimes called the Very Rare Event
  - The DBE became 2/3 of the MCE
  - Code focus became preventing collapse under MCE

Performance Based Engineering

- In 1991-1997, a new seismic retrofit guideline document (FEMA 273) became available that, for the first time, defined various performance levels:
  - Operational
  - Immediate Occupancy
  - Life Safety
  - Collapse Prevention
- When coupled with defined ground motion, a *Performance Objective* is formed. For example
  - Life Safety for the DBE
  - Collapse Prevention for the MCE
- Due to the many uncertainties involved, ability to predict or design to these objectives is limited, but the terminology forms a convenient system and has started a movement for better communication

Performance Based Engineering

- Current development of PBE is concentrating on estimating in probabilistic terms the primary losses from earthquake shaking
  - Casualties
  - Repair costs
  - Loss of use of building
  - Politically incorrectly called “death, dollars, and downtime”
- Communication with stakeholders may be more direct, but the acceptability by stakeholders of the probabilistic basis is unclear.*