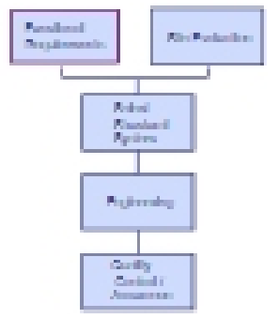
Overview of the Basic Seismic Resistant Design Process

- A quick look at the overall design process.
- Then look at some basic reasons for using nonlinear response to help us achieve performance objectives

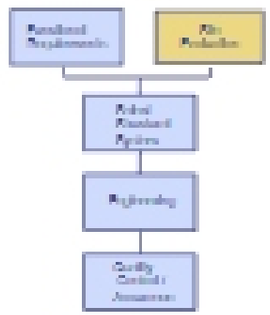
Basic Steps in the Design Process



Functional /Operational Requirements

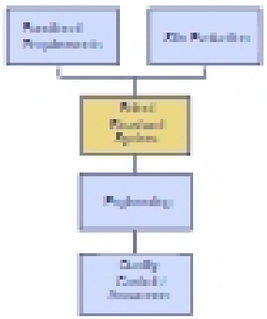
- Loading - Dead, live, etc.
- Spatial requirements (minimum area, height limits, interior open space, etc.)
- Operating restrictions (deflection, settlement, vibration limits)
- Expected life of structure
- Time available for construction
- Local cost of materials/labor
- Value of money
- Assess owner's aversion to risk
- Establish performance levels and key response parameters for frequent, rare and very rare seismic events and wind storms.

Site Evaluation



- Settlement potential
- Thermal setting
- Wind
- Mechanical vibration (trains, etc.)
- Seismic
  - ✓ Fault rupture
  - ✓ Differential ground movement
  - ✓ Liquefaction potential
  - ✓ Slope instability
  - ✓ Tsunami and seiche
  - ✓ Fire and flood
  - ✓ Ground shaking

Selection of Structural System

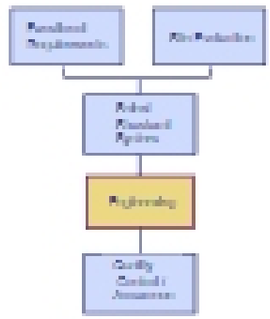


Typically, several types of structures are picked and investigated at least through the preliminary or schematic design stage. Consideration to alternative:

- *Materials for structural and non structural elements*
- *Connection types (fixed, partially restrained, etc.)*
- *Configuration (regular or not?)*
- *Load carrying system (complete vertical and horizontal load systems)*
- *Type of foundation*

Assess seismic and functional performance, and economic costs.

Engineering



Performance Based Format: establish that design satisfies performance criteria set for very rare, rare and frequent earthquakes.

Preliminary Design *Simple methods to develop structure that performs well.*

Detailing *Detail elements, connections of structural elements, attachments of non structural elements to achieve desired capacities and performance.*

Final Design *More refined methods used to fine tune building design to achieve performance goals (physical and economic).*

Probabilistic Performance Evaluation *Assess sensitivity of final structure to various sources of uncertainty and randomness.*

Engineering: Preliminary Design

Generally most important design stage. Focus on simple methods to develop structure that performs well (proportions, load path completion, stiffness, strength, etc.)

Iterative Process:

- ✓ Immediate Occupancy Goal: Elastic Analysis, very simple models and elastic spectrum
- ✓ "Life Safe" Goal: Elastic analysis, and "equiv. elastic" spectrum.
- ✓ Collapse Prevention Goal: Simplified nonlinear analysis, nonlinear design response spectrum.

⇳ Integrate design requirements

⇳ Evaluate designs

⇳ Re-do, if needed

Engineering: Detailing

Current codes do not attempt to relate details quantitatively to predicted deformation capacities. Nominal "ductile" details typically used -- relatively non-deteriorative and insensitive to loading history effects.

- *Tend is towards identifying qualitative categories, such as "special," "intermediate" and "ordinary" details which possess different abilities to deform inelastically.*
- *FEMA 350-352 utilize "prequalified" connections for which detailed design procedures have been calibrated by testing and analysis. There are prohibitions against extrapolation without additional testing and analysis.*

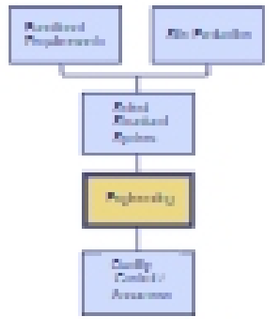
Engineering: Detailing

PBEE format: Design using computed estimates of demands.

- → Immediate Occupancy Goal: Focus on strength. Some damage permitted.
- → Life Safe Goal: Focus on triggers of expensive/hazardous behavior (spalling, buckling, falling hazards, etc.)
- → Collapse Prevention Goal: Focus on ultimate deformation capacity of member, connection and system that would lead to partial or global collapse of structure.

→Integrate and evaluate

Engineering: Final Design



Generally most analysis-oriented step.

Focus on refined methods to predict/evaluate demands on nearly completed structural design.

Iterative Process:

- → *Immediate Occupancy Goal:* Elastic Analysis, refined models and elastic spectrum, 2D vs 3D
- → *"Life Safe" Goal:* Elastic analysis, and "equiv. elastic" or nonlinear spectrum.
- → *Collapse Prevention Goal:* Nonlinear analysis (static push-over with nonlinear design response spectrum, or dynamic time history analysis).

→ Integrate design requirements

→ Evaluate designs (details, goals)

→ Re: do it needed

Engineering: Reliability Assessment

Infrequently done at present

Focus on refined methods to assess reliability of structure being able to achieve performance objectives

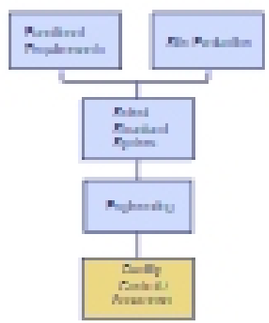
Iterative Process: (see FEMA 350-352)

- → *Immediate Occupancy Goal:* Elastic Analysis, refined models and elastic spectrum, 2D vs 3D
- → *"Life Safe" Goal:* Elastic analysis, and "equiv. elastic" or nonlinear spectrum (→1a).
- → *Collapse Prevention Goal:* Nonlinear analysis (static pushover with nonlinear response spectrum, dynamic time history analysis, etc.).

→ Integrate performance information

→ Evaluate confidence in achieving objectives

Quality Control/Assurance



Engineering Quality

Vision 2000 Recommends Engineering Peer Review

- ✓ Safety Critical and Essential/Hazardous performance objectives.
- ✓ Advanced or unusual technologies
- ✓ Rehabilitation projects involving untested details
- ✓ Complex or important structures

Should include all stages of design: establishment of project goals and procedures, Schematic Design Phase, Design Development Phase, and Construction Document Phase