BASIC CONCEPTS: SEISMIC DESIGN & ANALYSIS

LOADING

EQUIVALENT LATERAL FORCE PROCEDURE (ELF, ASCE 7-16 12.8)

MODAL RESPONSE SPECTRUM ANALYSIS (MRSA, ASCE 7-16 12.9.1)

LINEAR RESPONSE HISTORY ANALYSIS (LRHA, ASCE 7-16 12.9.2)

DUCTILITY

LINEAR ANALYSIS: ELF, MRSA OR LRHA

PERFORMANCE-BASED (NONLINEAR) PROCEDURES

Pushover analysis

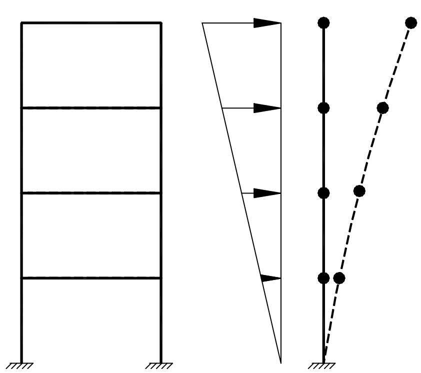
Nonlinear response history analysis (NRHA, ASCE 7-16 Chapter 16)

LOADING

Earthquakes cause buildings to accelerate and displace laterally (and sometimes vertically), which generates forces within the structure. This 'seismic loading' can be modelled by engineers in a variety of ways:

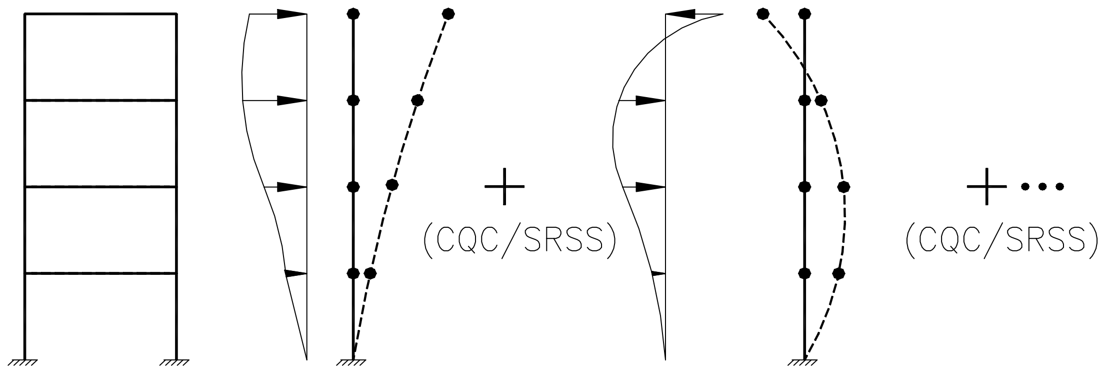
EQUIVALENT LATERAL FORCE PROCEDURE (ELF, ASCE 7-16 12.8)

Lateral loads that are the 'static equivalent' of the peak seismic response are applied to the model. This assumes the building sways like a simple pendulum.



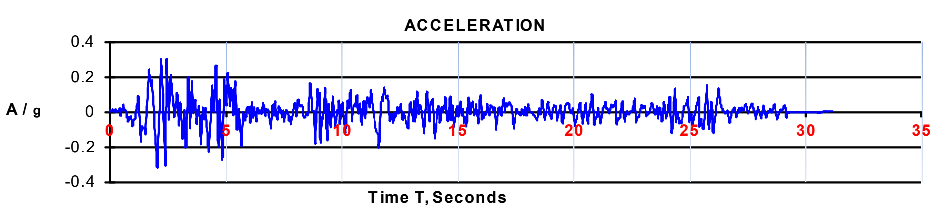
MODAL RESPONSE SPECTRUM ANALYSIS (MRSA, ASCE 7-16 12.9.1)

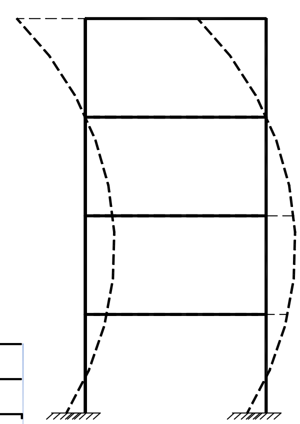
ELF is a basic approximation. All structures have a more complex dynamic response to earthquakes. MRSA captures this, statistically summing the various peak responses that can occur.



LINEAR RESPONSE HISTORY ANALYSIS (LRHA, ASCE 7-16 12.9.2)

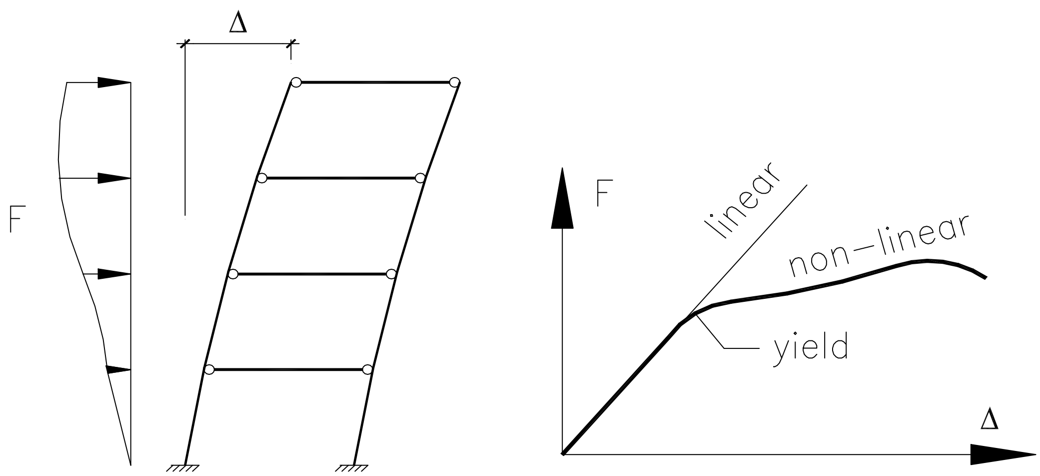
This subjects a model to real ground-motion records. It captures the dynamic and time dependent response of a structure. It is the most accurate method available for representing seismic loading.





DUCTILITY

It is generally not feasible to design structures in areas of high seismicity to remain elastic; member sizes become too large. Instead, structures are designed to yield at a given level of seismic load, form a mechanism and plastically displace.



Ductility is the measure of how much plastic strain a single element or whole structure can experience before it is damaged to a point where it can no longer sustain loading. It is usually expressed as a multiple of the yield strain. There are various options to suitably account for ductility (i.e. a nonlinear response) in analysis.

LINEAR ANALYSIS: ELF, MRSA OR LRHA

In ELF, MRSA or LRHA, ductility is accounted for with a single reduction factor that is applied to seismic loads, and thus affects the structure as a whole. The reduction factor value is based on the least ductile element. The correlation of a linear analysis to the real structure's response is largely dependent on the suitability of the ductility factor that is assumed. A structure is designed or assessed based on the ratio of member forces to conventional sectional capacities and displacement limits.

PERFORMANCE-BASED (NONLINEAR) PROCEDURES

Specific stress/strain relationships are defined for each element in a structure. Assessment is based on damage (plastic strain) sustained and displacement limits. There are two main methods for this form of analysis:

Pushover analysis

A static set of seismic loads is incrementally applied and the structure is literally pushed over as elements progressively yield.

Nonlinear response history analysis (NRHA, ASCE 7-16 Chapter 16)

Real ground-motion records are applied to the base nodes of a model. The structure's real time nonlinear response is recorded; the most accurate method available. Loads redistribute and the structure's dynamic characteristics update in each time step as elements yield and degrade. It facilitates the design of focused and efficient strengthening solutions.

REFERENCES:

1. Joe White and Hamish McKenzie: “Seismic strengthening of the Majestic Centre, a 30-storey office tower in Wellington, New Zealand,” The Structural Engineer, April 2017, Page 9-10.
2. “Minimum Design Loads and Associated Criteria for Buildings and Other Structures (ASCE/SEI 7-16),” ASCE, Reston, VA, 2017.