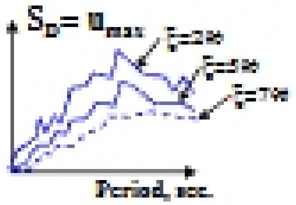
Elastic Design Response Spectra

Envelop of a computed peak dynamic response parameter for single degree of freedom elastic systems having a range of periods, for a given ground motion and viscous damping ratio

$$ma(t) + 2\xi\omega v(t) + Kd(t) = -ma_g(t)$$



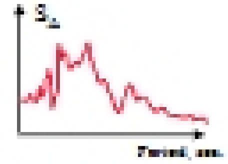
Uses

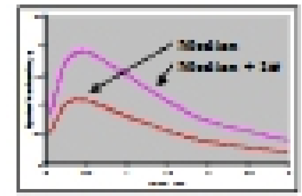
- *Characterize ground motions and assess demands on various types of simple structures.*
- *Basis for computing design displacements and forces in SDOF and MDOF systems expected to remain elastic.*
- *Basis for developing design forces and displacements in nonlinear systems (two approaches):*
  - *Modified elastic spectrum to account for nonlinearity*
  - *Equivalent elastic SDOF system*

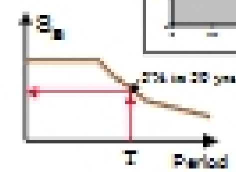
Design Response Spectrum

Topics

- ***Developing design spectra from site specific ground motion time histories***
- ***Selection of damping values***
- ***Plotting formats***
- ***Analytic relations for developing Elastic Design Response Spectrum***
  - *Deterministic*
    - Statistical "attenuation" relationships
    - Simplified empirical relationships (e.g., Newmark-Hall methods)
  - *Uniform Hazard Spectrum*
    - Basic approach (From USGS hazard maps used in current codes)
    - Current spectra formulations found in codes (how do they relate to theory?)

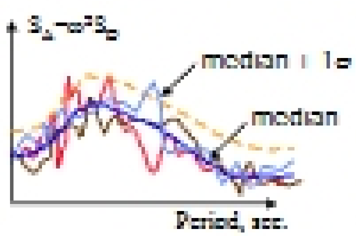






Smooth Design Response Spectrum from Ground Motion Records

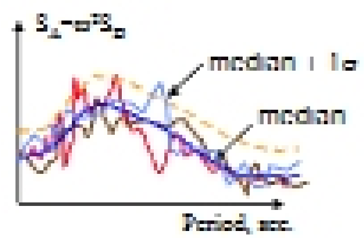
- *Response Spectrum for actual ground motions are quite irregular.*
  - ***Don't use individual spectrum for design***
  - *They can be used for analysis to assess response to a particular earthquake.*



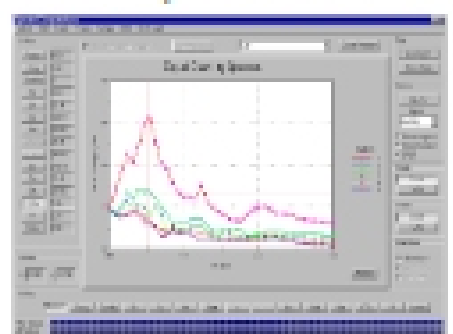
- *Use suites of ground motions representing:*
  - *A specific deterministic design earthquake (e.g., M ? at 10 km)*
  - *Match a stipulated design response spectrum (e.g., match code spectrum)*
  - *A range of earthquakes types corresponding to the design/expected seismic hazard at the site.*
- *The "design response spectrum is obtained statically from all records." The resulting "median" spectrum will be relatively smooth. The COV or Standard Deviation (σ_{ln}) can be used to establish a design spectrum with a desired probability of exceedence.*
- *Note: Various programs do this automatically.*

Generate Smooth Spectrum from Records

- ***PEER NGA Database will search for particular types of records and plot scaled response spectrum. Can download tables of spectral values for different periods and damping ratios***



- ***Bispec and other programs***
  Permit user to input a suite of ground motion records and will find median and median plus 'x' σ values



Viscous Damping

Viscous damping is a convenient analytical concept to account for general energy dissipation in a system and analytical uncertainties.

- *Friction between and with structural and non structural elements.*
- *Localized yielding due to stress concentrations and residual stresses under low loading and gross yielding under higher loads.*
- *Energy radiation through foundation.*
- *Aeroelastic damping.*
- *Viscous damping.*
- *Analytical modeling errors.*

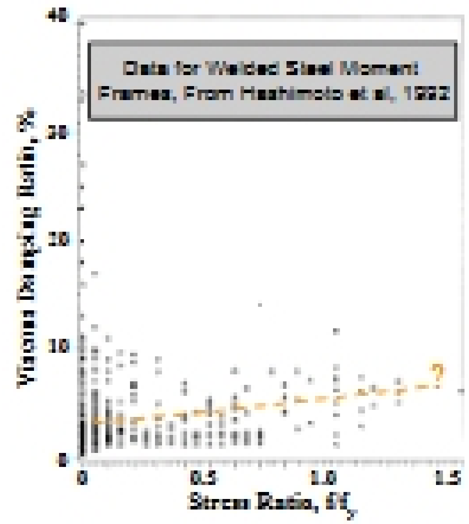
Damping is generally a function of:

- *Material*
- *Amplitude (stress)*
- *Type of nonstructural elements*
- *Type of foundations and supporting soils*
- *Frequency*
- *Type of connections*
- *Complexity of model (different parts of structure will be responding differently)*

Constant viscous damping is a simplification.

Damping can produce substantial forces that are only crudely modeled compared to inertial and restoring forces.

Data on Viscous Damping



References

- *NRC, "Regulatory Guide 1.61, Damping Values for Seismic Design of Nuclear Power Plants," U.S. Atomic Energy Commission., Oct. 1973.*
- *Chen,D., "Damping in Building structures During Earthquakes, Test Data and Modeling," NUREG/CR 3006, Jan. 1983.*
- *Hashimoto, P. et al, "Review of Regulatory Guide 1.61 Structure Damping Values for Elastic Seismic Analysis of Nuclear Power Plants," Nuclear Regulatory Commission, 1992*

Recommended Design Damping Values

- *Many codes stipulate 5% viscous damping, unless a more properly substantiated value can be used.*
- *Note that actual damping values for many systems, even at higher levels of excitation are less than 5%.*

Structure Type	Working Stress Range (less than about 1/2 yield stress)			At or Just Below Yield Point		
	NRC 1.61	Clough	Hashimoto	NRC 1.61	Clough	Hashimoto
Welded Steel	2	2 to 3	2.5	4	5 to 7	4**
Bolted Steel	4	5 to 7	4.5	7	10 to 15	6
Prestressed Concrete	2	2 to 3	TBD	5	5 to 7	TBD
Reinforced Concrete	4	3 to 5	4	7	7 to 10	7

* lightly shaded sections represent lower values in range

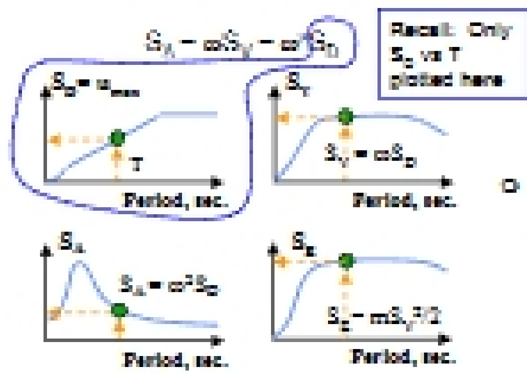
** friction bolted connections same as welded steel

TBD: values to be determined when sufficient data is available

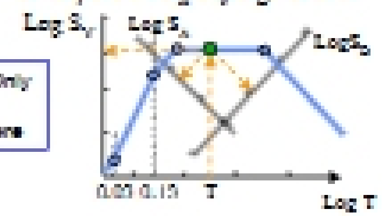
Formats for Plotting Spectra

A variety of formats used

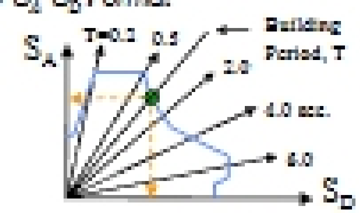
- S_A- T, S_V- T, S_D- T and S_E- T



- *Tripartite S_A-S_V-S_D Format*



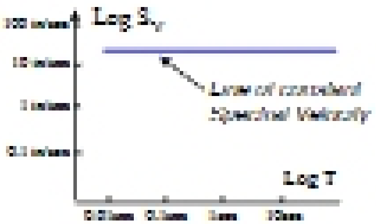
- *S_A-S_D Format*

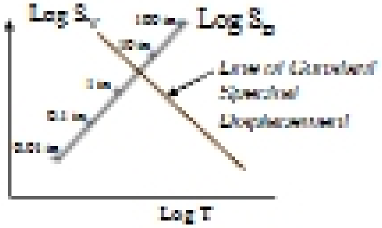


Basis of Tripartite Graph Paper

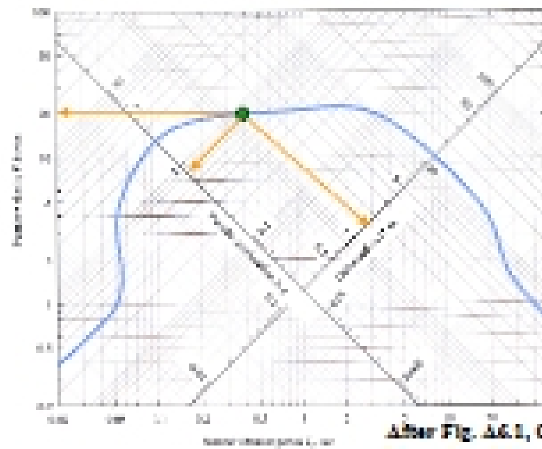
$S_V = S_A/\omega = S_A T/2\pi$
$= \omega S_D = 2\pi S_D/T$

- line of constant spectral acceleration has a slope of 1 on a log-log plot of S_V vs. T
- line of constant spectral displacement has a slope of -1 on log-log plot of S_V vs. T





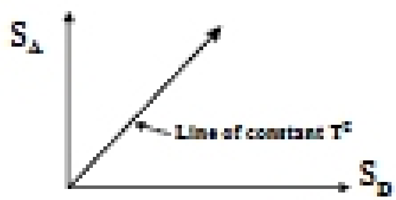
Tripartite Response Spectrum

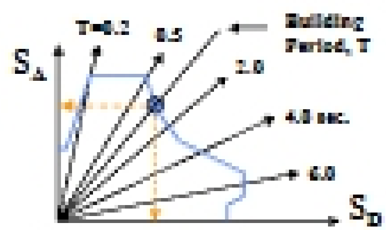


After Fig. A6.1, Chopra, *Dynamics of Structures*

S_A-S_D Format

- *An alternative form of plotting spectra has been introduced recently and has started to appear in building codes.*
- *Intent is to plot information on acceleration (force) and displace ment on same graph with out complexity of tripartite paper*
- *Based on: $S_A = \omega^2 S_D \rightarrow \omega^2 = S_A/S_D$*
- Used to interpret nonlinear response in conjunction with "Capacity Spectrum" and "Yield Point Spectrum" Methods Discussed later





Analytic Relations for Developing Elastic Design Response Spectrum

- ***Deterministic Approaches***
  - *Statistical attenuation relations for a given magnitude, distance, soil condition, fault type, etc.*
  - *Simplified empirical methods by Newmark and others for a given peak ground acceleration*
- ***Spectra based on Probabilistic Hazard Analysis***
  - *Uniform hazard methods (focus on USGS data)*
  - *NEHRP Tentative Provisions for Seismic Regulations for New Buildings*