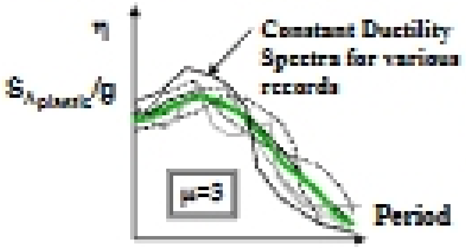
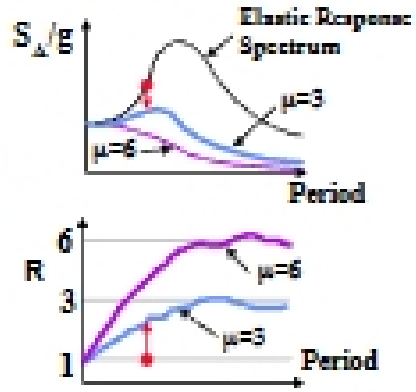
# *Inelastic Design Response Spectra*

- *Developed by statistical processing of actual nonlinear spectra for ground motions, hysteretic characteristics, ξ and damage indices of interest.*




- *Developed by modification of an elastic design spectrum.*






# *Scope of Discussions*

*Prefer:*

- Actual spectra when site specific motions used.
- Empirical modification factors R and γ when elastic response spectrum specified.

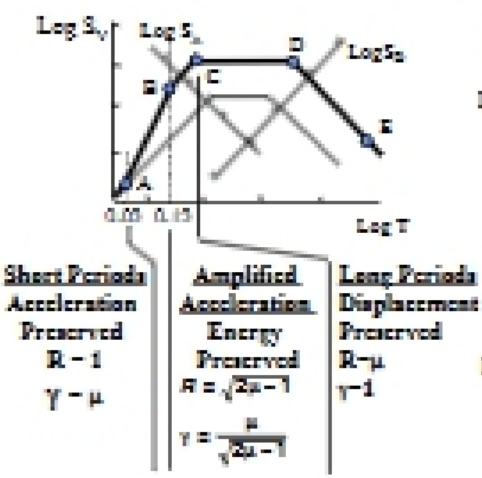
→ *Look at typical empirical modification methods for ideal EPP systems*

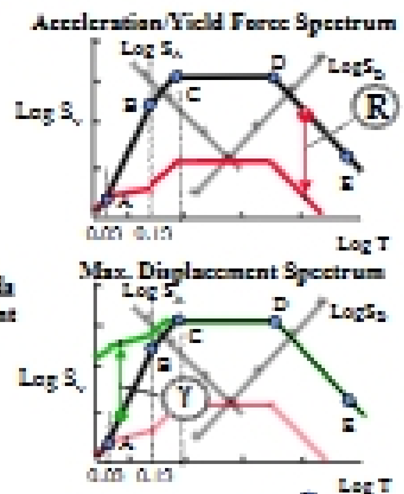
- Newmark and Hall (et al)
- Multi linear relations (Hidalgo, Riddell, ATC 32)
- Continuous functions (Miranda, Krawinkler, et al)

- ***Next Section:*** *Examine briefly effect of and modifications for:*
  - *P Δ effects*
  - *Shape of hysteretic loops*
  - *Special ground motion characteristics*
    - soft soils
    - near fault motions
  - *Viscous damping*
  - *Duration of shaking other damage indices*
- ***Compare to code provisions***
- ***Then:*** *Extend to multiple degree of freedom systems*



# *Newmark and Hall IDRS Method*



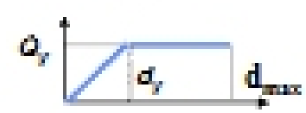



# *Newmark and Hall IDRS (Continued)*

***This can easily be plotted using conventional axes.***

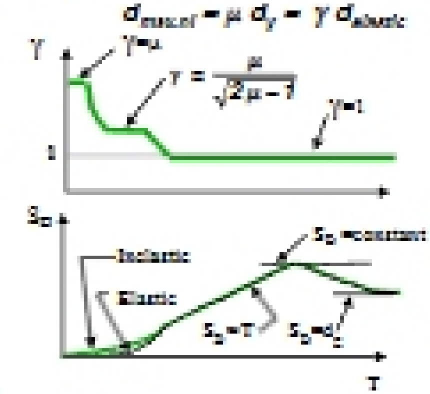

*Note:* $Q_y = S_{Ay} m$

*So:* $d_y = S_{Ay}/\omega^2$




***To get maximum displacement***

$d_{max,i} = \mu\, d_y = \gamma\, d_{elastic}$



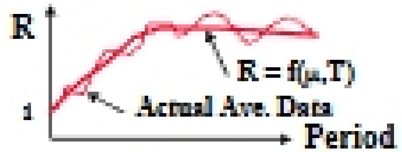
# A Note on Displacement Estimates

- $d_{max} = \mu d_y = \mu Q_y/K$
  $= \mu(Q_{elastic}/R)/K$
  $= (\mu/R)(S_{A_{elastic}} M)/K$
  $= (\mu/R)\, S_{D_{elastic}}$
  $= \gamma\, S_{D_{elastic}}$

So: $\gamma = \mu / R$

*Thus, if we have a relation that defines R as a function of μ [$R=f(\mu,T)$], we can estimate the maximum displacement using $\gamma = \mu/f(\mu,T)$.*

- *However, the R function does not exactly fit the data ($\mu_{actual} \neq \mu_{target}$), so if we use $\gamma = \mu_{target}/R$ our results will be slightly in error.*



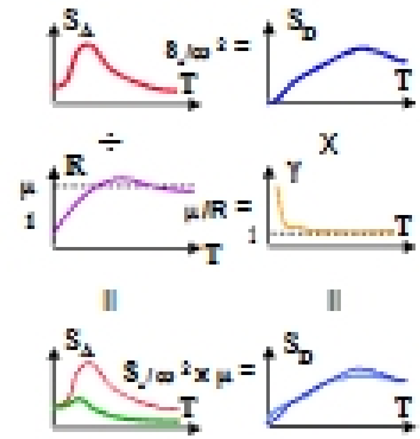

- *We only have a few analytical expressions for $\gamma = f(\mu, T)$*



# Empirical Modification Factors for IDRS

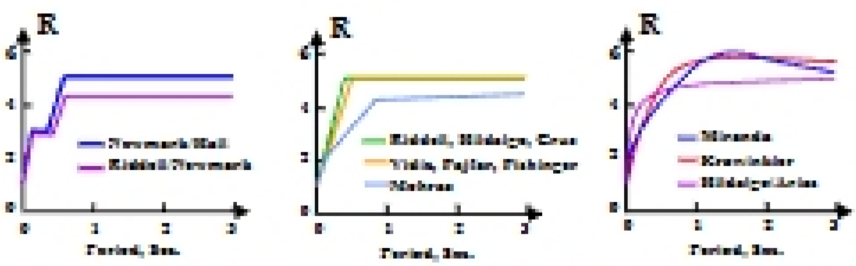
*Empirically derived equations have been developed to estimate R for a given displacement ductility demand on a structure.*

*Comprehensive review by: E. Miranda and V. Bertero in "Evaluation of Strength Reduction Factors for Earthquake-Resistant Design," Earthquake Spectra, EERI, Vol. 10, No. 2, 1994.*






# Some R factors for μ = 5




Simplified form used in several codes and guidelines

Analytical format good for use with statistical relationships for elastic spectrum



# Miranda's Relationships for R

***Acceleration Modification Factors***

*See: E. Miranda, "Site Dependent Strength Reduction Factors, "Journal of Structural Engineering, ASCE, Vol. 119, No. 12, Dec. 1993.*

$$R = \frac{\mu - 1}{\Phi} + 1 \geq 1$$

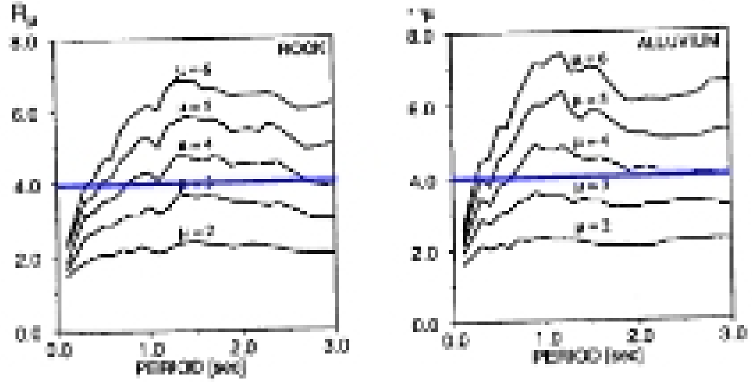
where Φ is a function of μ, T and soil conditions, such that

$$\Phi = 1 + \frac{1}{10T - \mu T} - \frac{1}{2T}\exp\left[-\frac{3}{2}\left(\ln T - \frac{3}{5}\right)^2\right]$$ for rock sites

$$\Phi = 1 + \frac{1}{12T - \mu T} - \frac{2}{5T}\exp\left[-2\left(\ln T - \frac{1}{5}\right)^2\right]$$ for alluvial sites

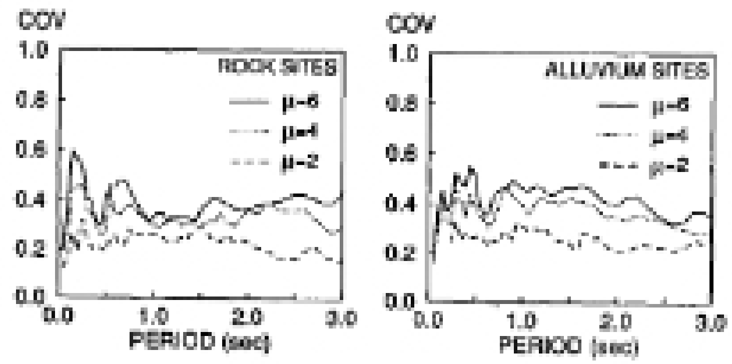
$$\Phi = 1 + \frac{T_g}{3T} - \frac{3T_g}{4T}\exp\left[-3\left(\ln \frac{T}{T_g} - \frac{1}{4}\right)^2\right]$$ for soft soil sites

## *Miranda Data for Rock / Alluvial Sites*



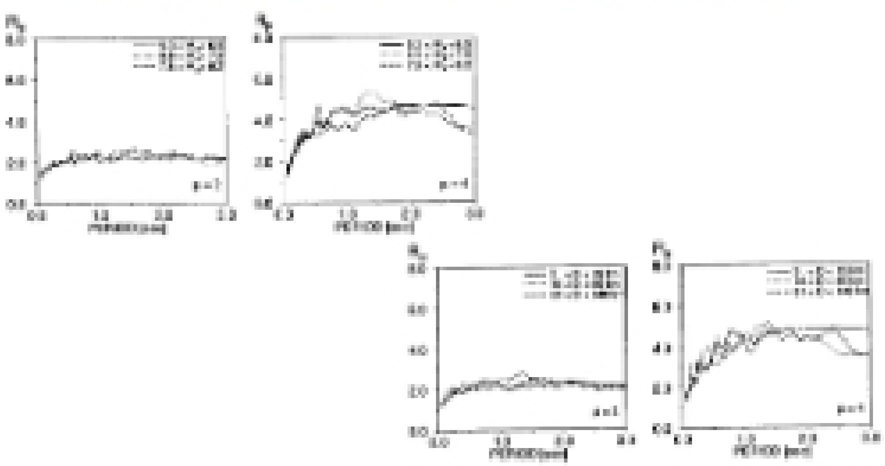



## *CoV for Rock/Alluvial Sites*






## *Effect of Distance & Magnitude*





## *Near-Fault and Soft Soil Sites*