Some Additional Effects of Ground Motion Characteristics on Inelastic Response

- *We have seen that the general dynamic characteristics of a ground motion have a big influence on inelastic response.*
- *Similarly, structural properties (T, ξ, Q_y, K, etc.) have a big effect.*
- *Before moving on, we will look at two other contributions to response:*
  1. *Duration*
  2. *Near-fault ground motions*

Duration of shaking

- *Generally, we do not worry about duration of shaking as peak inelastic response tends to remain constant following a few seconds of shaking*
- *Earthquake duration can be important were the structure is susceptible to:*
  - → *Cyclic deterioration*
  - → *Geometric nonlinearies*
  - → *Low-cycle fatigue*

Near-fault ground motions

- *Different frequency and temporal characteristics*
- *Large accelerations*

Low-Cycle Fatigue

Popular Damage Index -- Park and Ang

- *Damage related to both peak displacement and total energy dissipation*

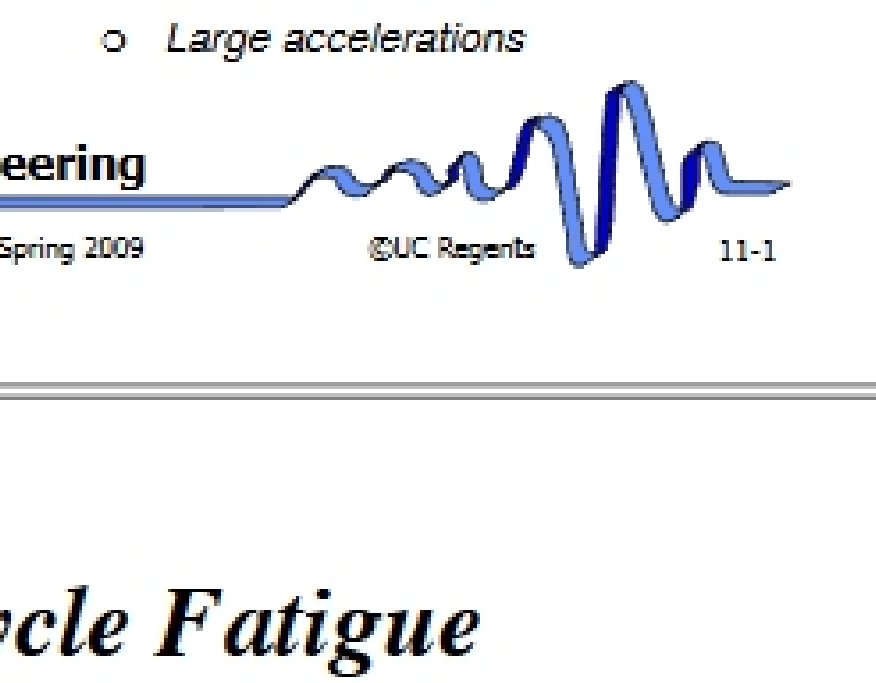
Or

$$DMI_{PA} = \frac{\delta_{max}}{\delta_u} + \beta \frac{E_{Hy}}{F_y \delta_u}$$

$$DMI_{PA} = \frac{\mu_{max}}{\mu_u} + \beta \frac{NE_{Hy}}{\mu_u}$$

If we know β, then we can determine the required value of μ_u for detailing or the value of μ_{max} for use with γ to determine R

$$\mu_{max} = \mu_u - \beta NE_{Hy} \text{ or } \mu_u = \mu_{max} + \beta NE_{Hy}$$



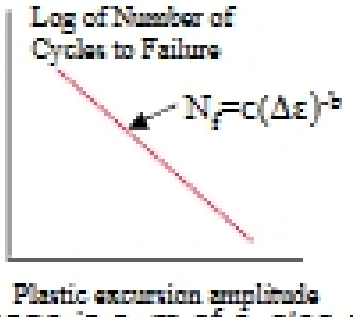
From: Teran-Gilmore and Jirsa, "Damage Model for Practical Seismic Design," Earthquake Spectrum, EERI, Aug. 05

Low-Cycle Fatigue

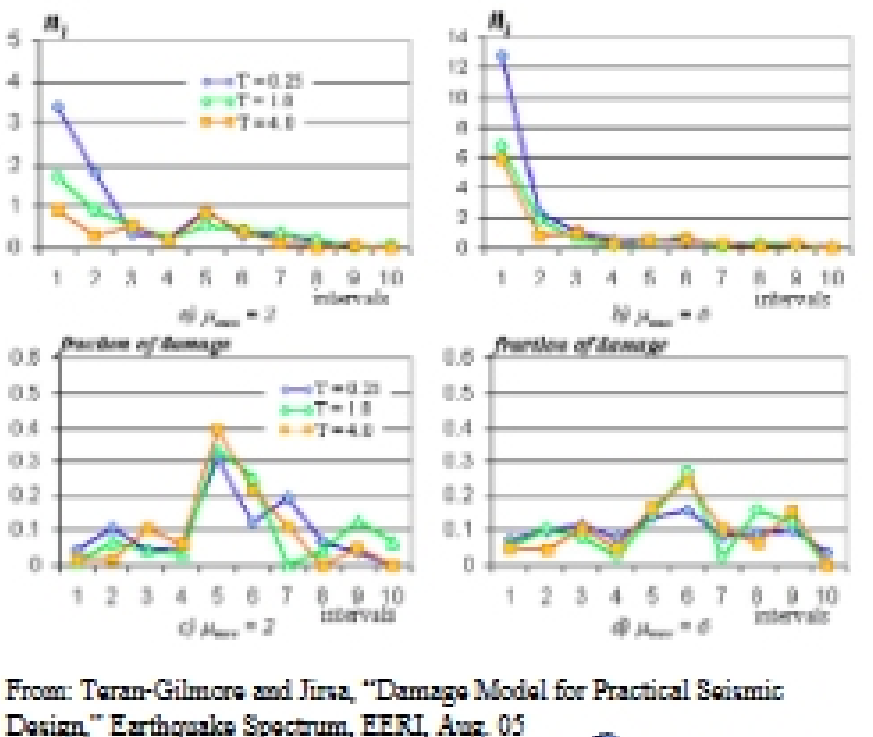
Low-cycle fatigue may control design for long duration events or fragile structures

Manson-Coffin Type Damage Mechanics Models

- *Park and Ang model suffers from theoretical limitations*
- *Larger cycles should cause disproportionately larger damage than smaller ones.*



- *Damage is sum of cycles at a specific amplitude level divided by number of cycles at that amplitude to cause failure*



$$DMI_{MH} = \sum_{i=1}^{NH} \frac{n_i}{N_i}$$

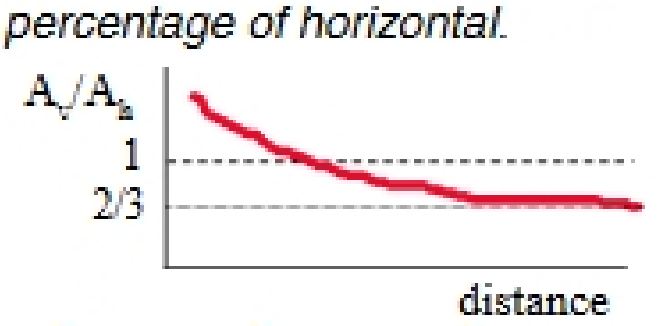
From: Teran-Gilmore and Jirsa, "Damage Model for Practical Seismic Design," Earthquake Spectrum, EERI, Aug. 05

Comments on Near-Source Motions

Generally, near-fault earthquake motions can be treated using the same basic approach discussed previously. But....

1. *More intense motions than previously considered in design*
   - Relatively few recorded large, near-field motions so uncertainty of estimates is high
   - Design criteria may thus change after each new major earthquake
   - Careful estimation of ground motion characteristics needed for design to avoid excessive demands.

2. *Vertical motion may be a higher percentage of horizontal.*



See paper by Bozognia and Campbell

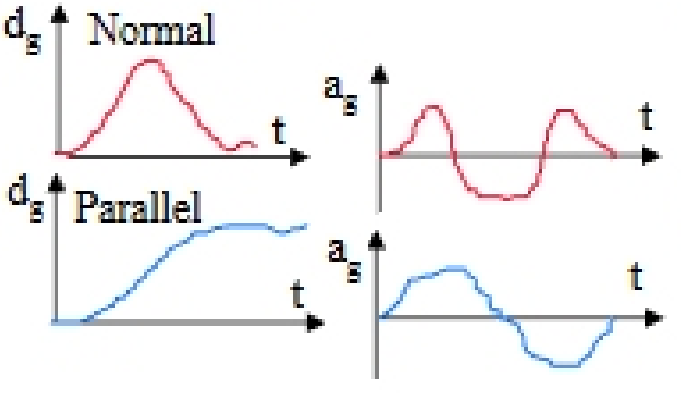
3. *Severe pulse-like motions*
   - T_p becomes longer with M, so many structures act like they are on amplified acceleration region of spectrum (energy preserved)
   - Damping is not going to help these structures very much

References

- *Bozorgnia, Yousef; Campbell, Kenneth W.; Niazi, Mansour, "Observed spectral characteristics of vertical ground motion recorded during worldwide earthquakes from 1957 to 1995," 12th World Conference on Earthquake Engineering New Zealand Society for Earthquake Engineering, 2000.*
- *Bozorgnia, Yousef; Campbell, Kenneth, "The vertical-to-horizontal response spectral ratio and tentative procedures for developing simplified V/H and vertical design spectra, Journal of Earthquake Engineering, Vol. 8, No. 2, 2004.*
- *Bozorgnia,Y. and Mahin, S., Ductility and strength demands of near-fault ground motions of the Northridge earthquake - Proceedings,6th US National Conference on Earthquake Engineering, EERI, 1998.*
- *Cuesta, I., Aschheim, M., and Fajfar, P., "Simplified R-Factor Relationships for Strong Ground Motions," Earthquake Spectrum, Vol. 19, No. 1, Feb. 2003.*

Near-Source Pulse Effects

- ***A controlling aspect of virtually all Los Angeles and San Francisco region design earthquakes.***
- ***Substantial differences exist between fault normal and fault parallel motions***



- ***Fault normal motion normally has more severe effect (response spectrum) than parallel motion.***
- ***Some studies available .... See Hall and Heaton paper & SAC Technical Reports.***
- ***Simplifications useful for assessing effects.***

Two important effects:

- ***Spectral Characteristics***
- ***Wave propagation effects (discuss later)***