A short course on

Nonlinear Finite Element Analysis

This video:

Nonlinear Dynamics in Seismic Design

Terje's Toolbox is freely available at terje.civil.ubc.ca
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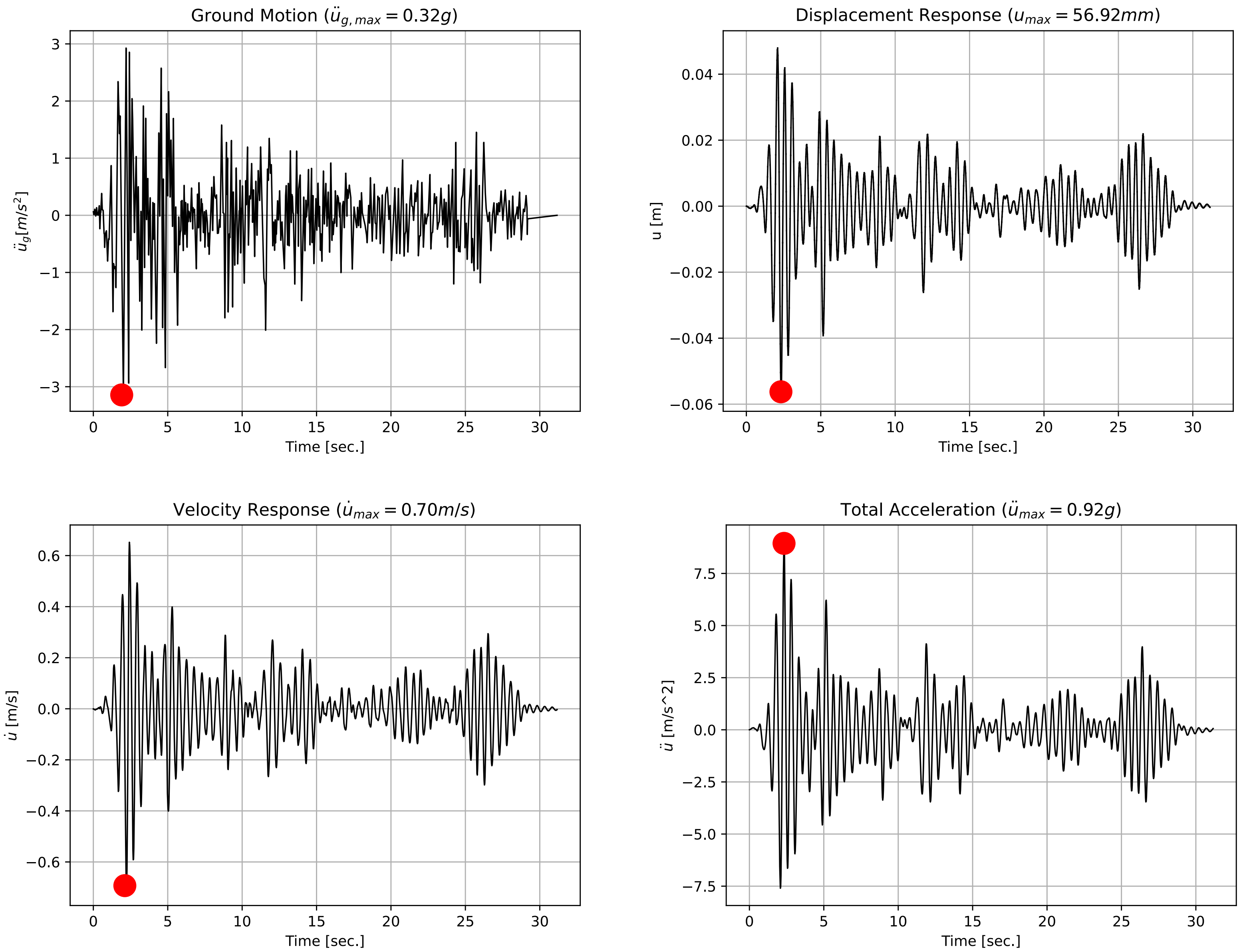
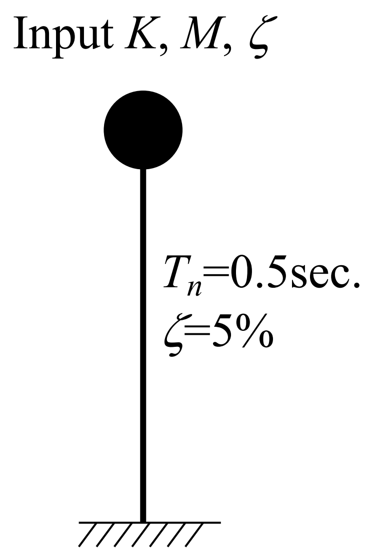
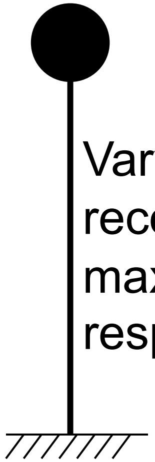
El Centro Responses



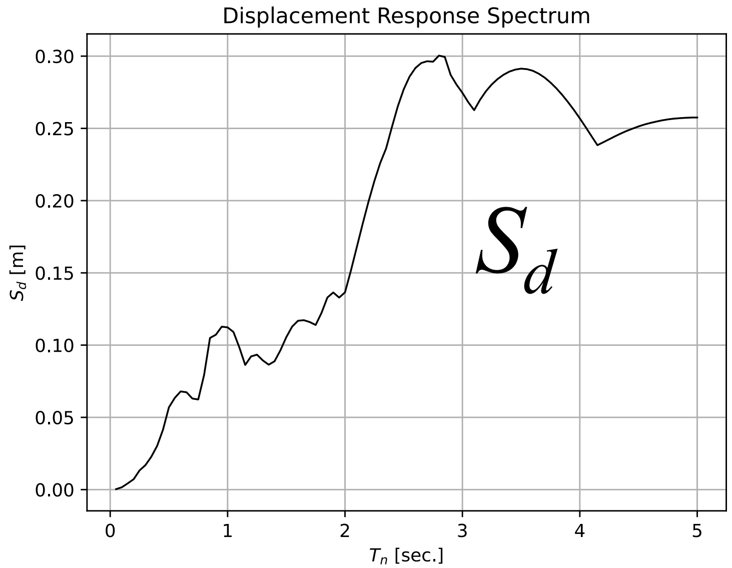


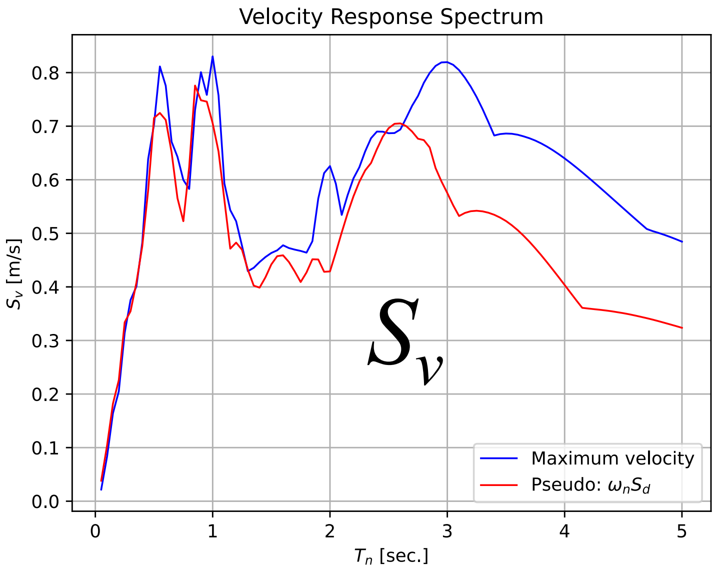
Good reference:
Chopra, Dynamics of Structures

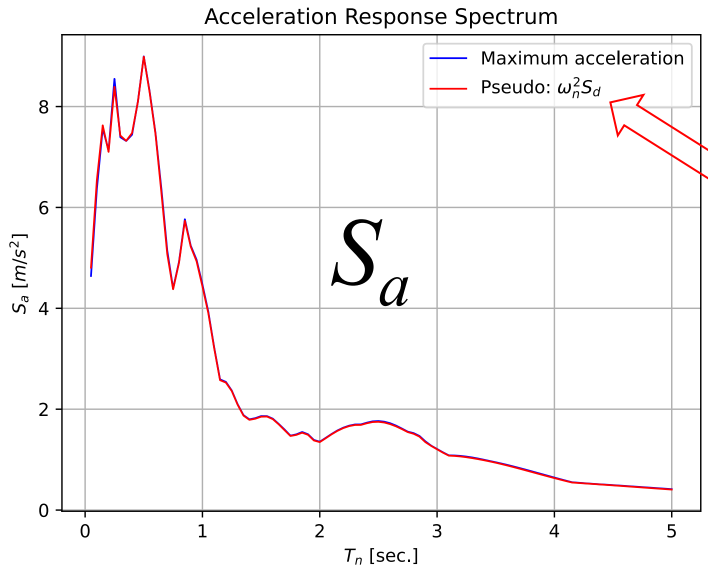
Response Spectra



Vary T_n and record maximum response







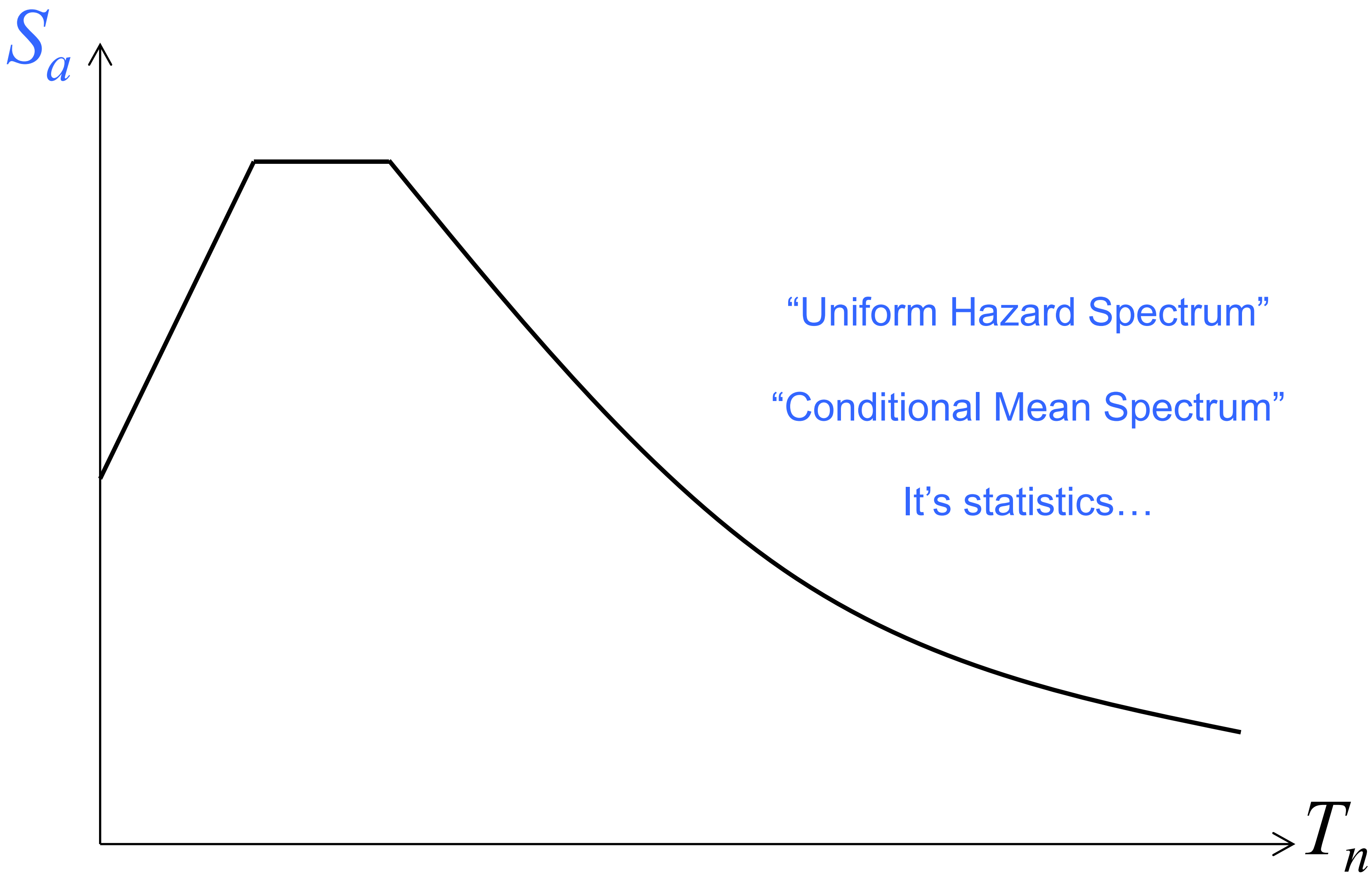
$$\omega_n = \sqrt{\frac{K}{M}}$$

$$K = M \cdot \omega_n^2$$

$$F(t) = K \cdot u(t)$$

$$= M \cdot \underbrace{\omega_n^2 \cdot u(t)}_{\text{"Pseudo-acceleration"}}$$

Design Spectra



"Uniform Hazard Spectrum"

"Conditional Mean Spectrum"

It's statistics…

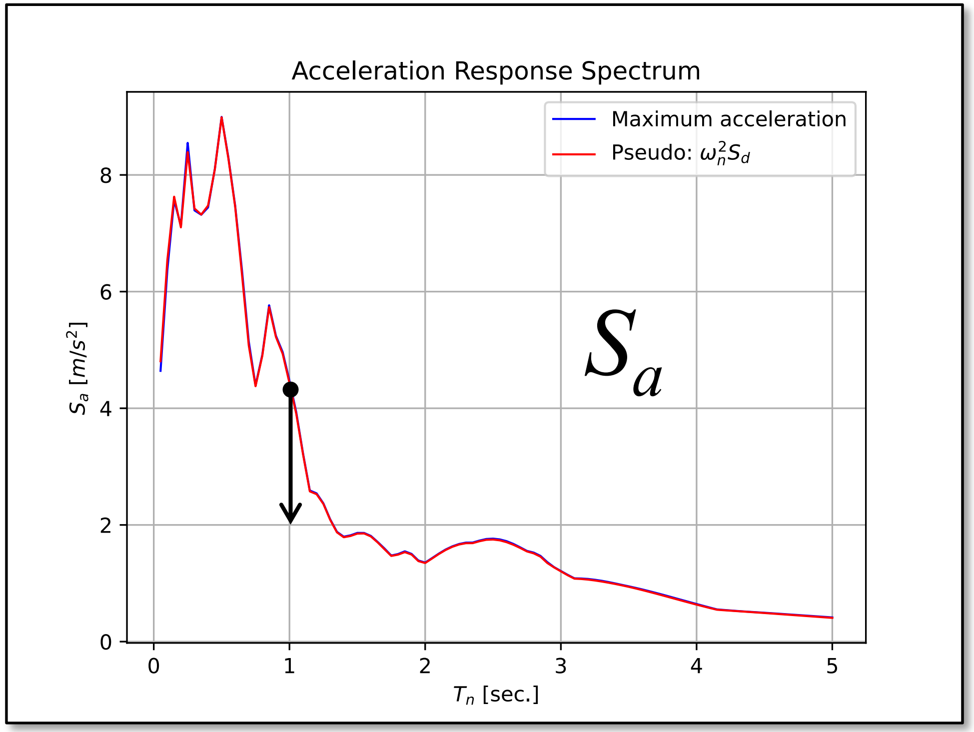
Ground Motion Scaling

Databases: PEER-NGA (East & West)

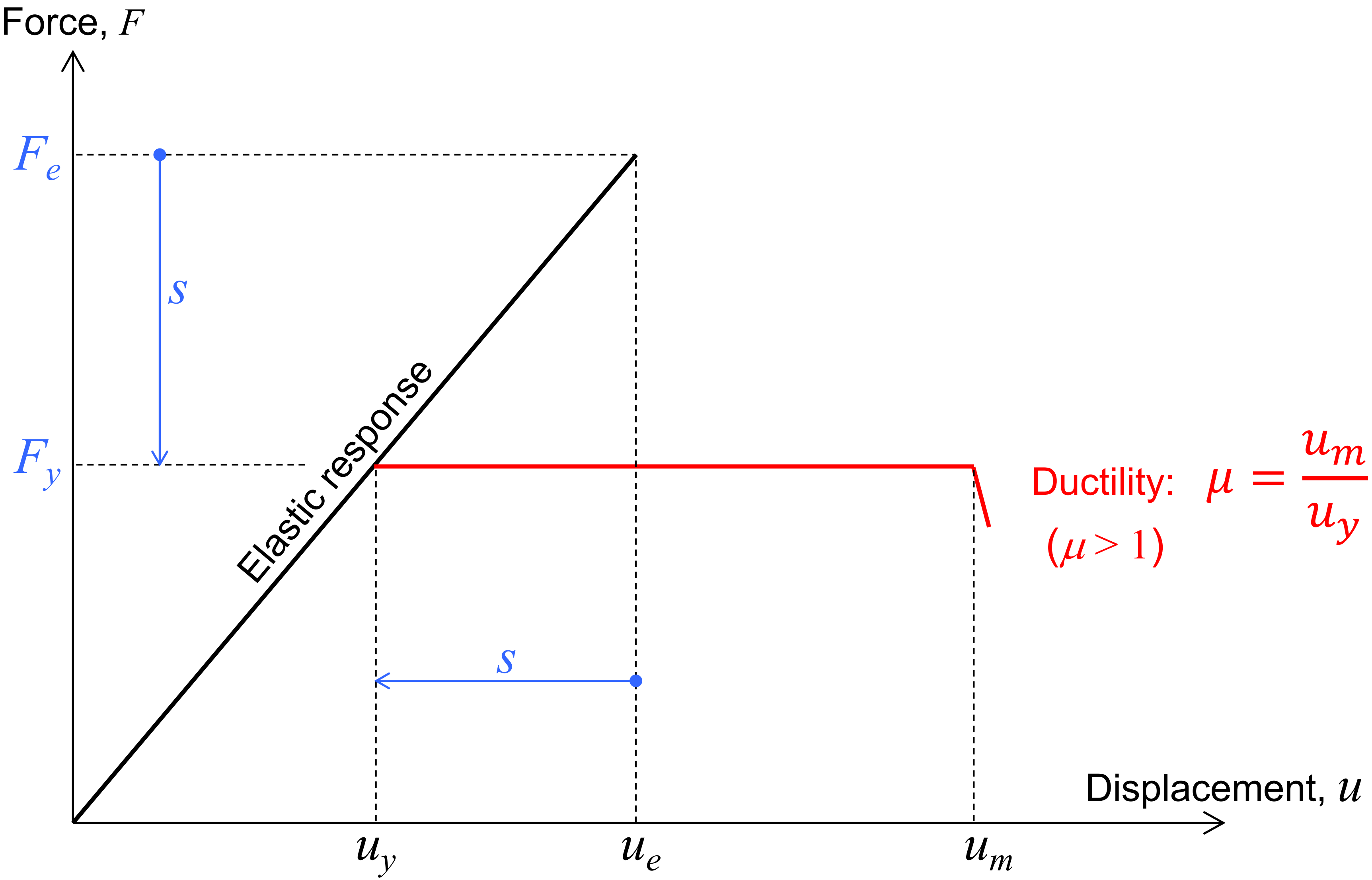
Easy and transparent scaling: Scale record to match $S_a(T_n)$

More complex scaling: Spectrum matching

Tools: QuakeManager, etc.



Response to ONE Ground Motion



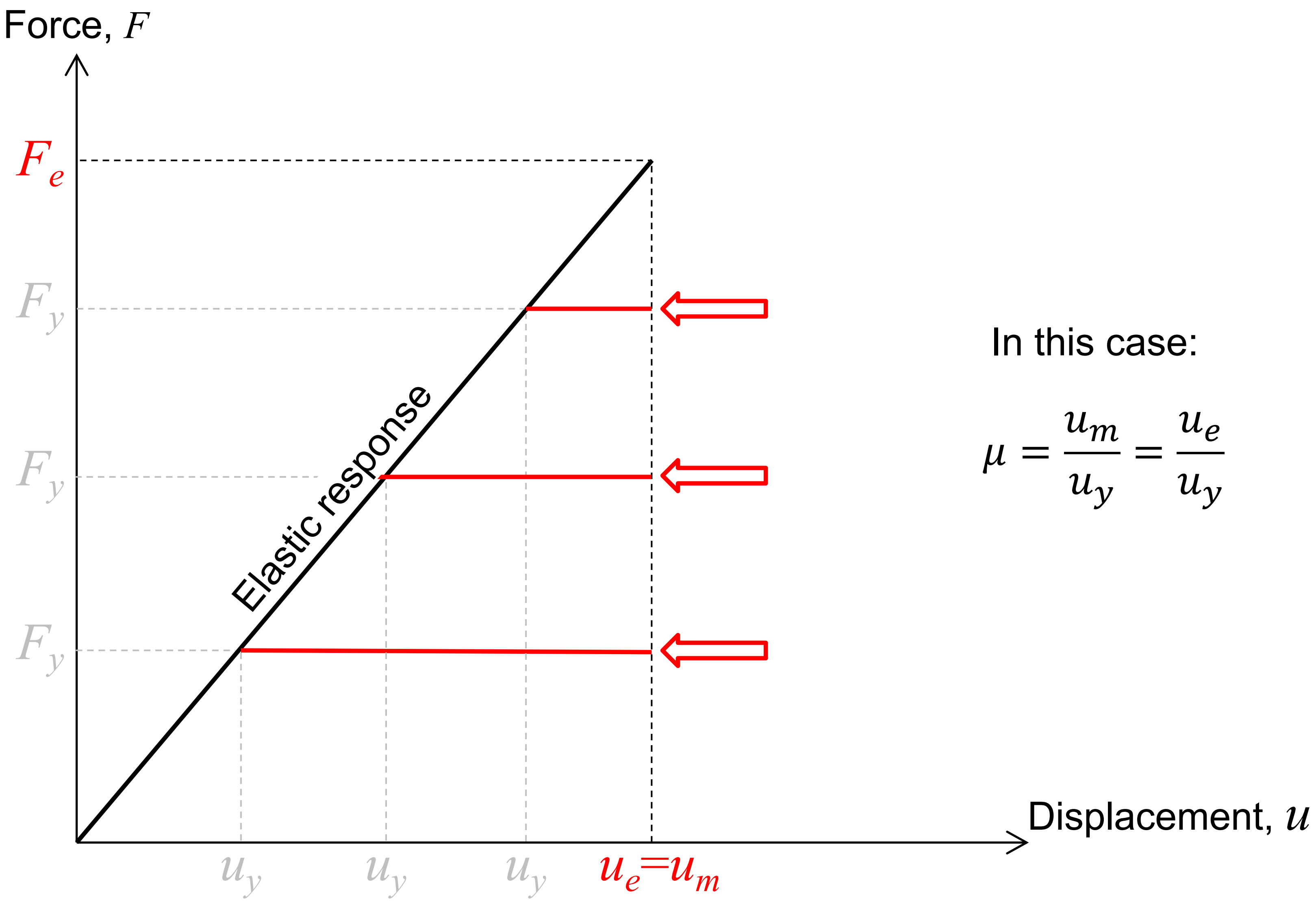
Relative strength: $s = \frac{F_y}{F_e}$

$(s < 1)$

Ductility: $\mu = \frac{u_m}{u_y}$

$(\mu > 1)$

Equal Displacement Rule



In this case:

$$\mu = \frac{u_m}{u_y} = \frac{u_e}{u_y}$$

Design

What is the ductility demand, μ, for a designed strength, F_y?

Run **linear** analysis → (F_e, u_e)

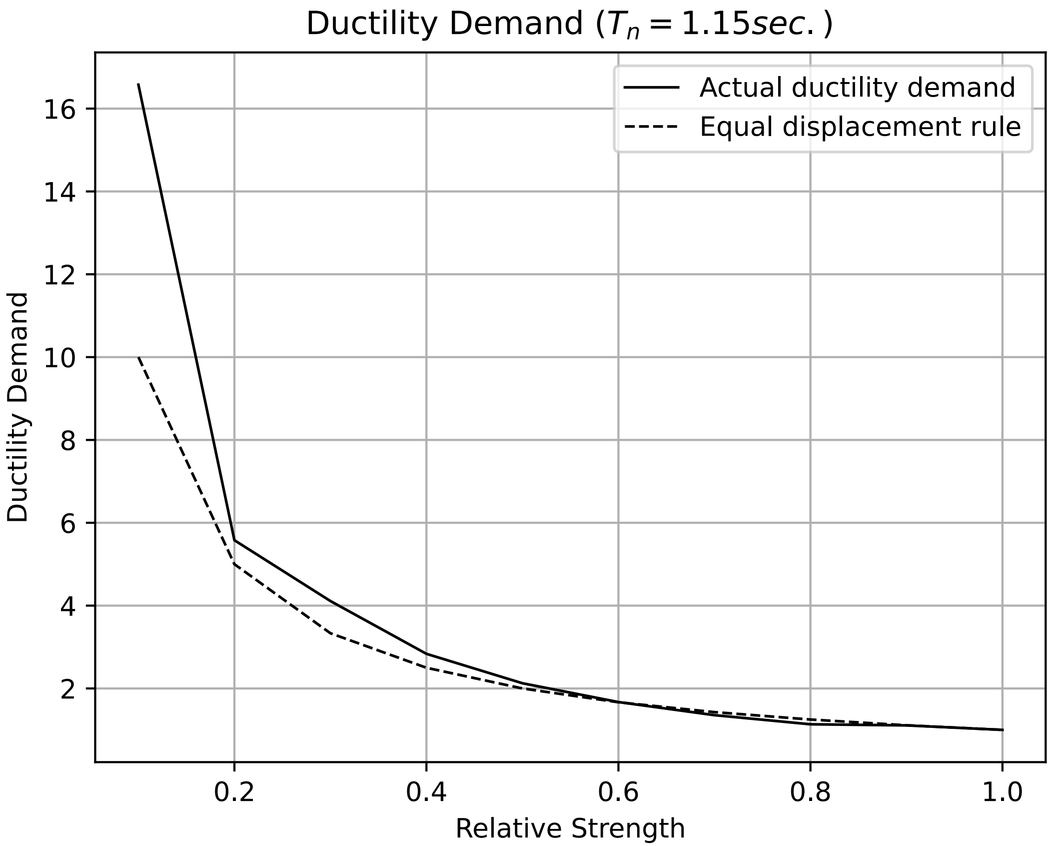
Specify strength by s → $F_y = s \cdot F_e$ → $u_y = s \cdot u_e$

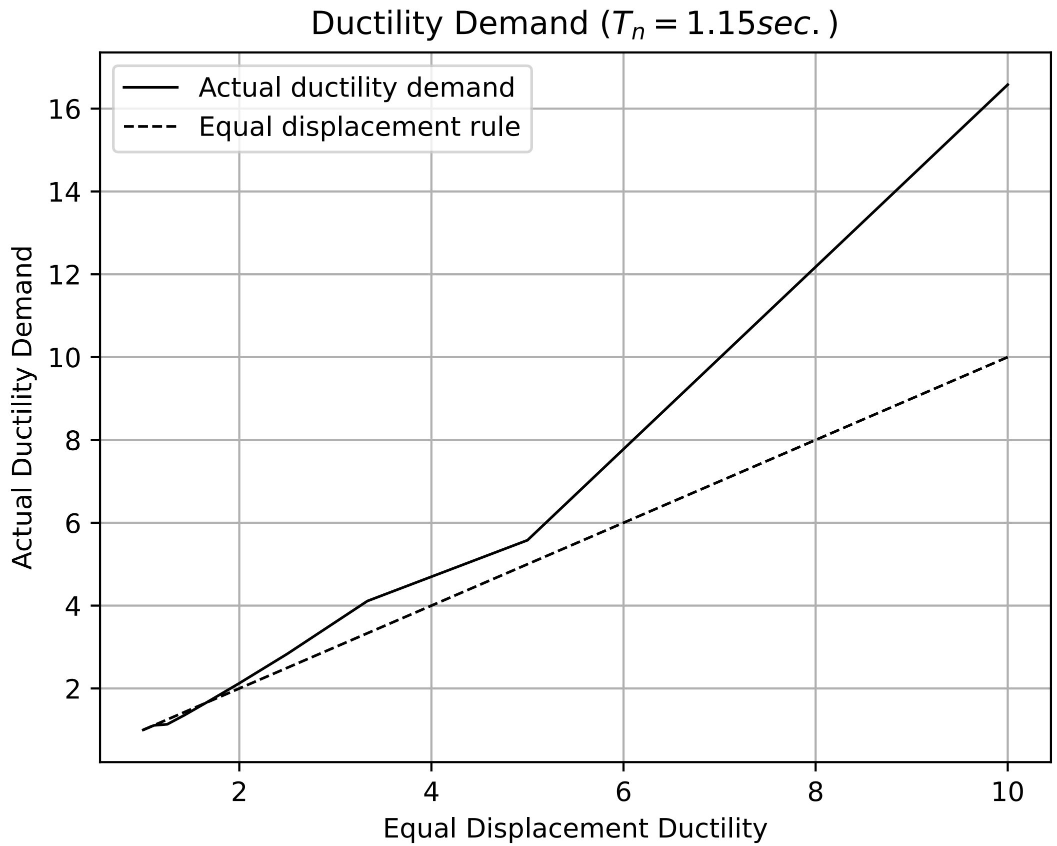
Run **nonlinear** analysis → u_m

Ductility demand: $\mu = u_m / u_y$

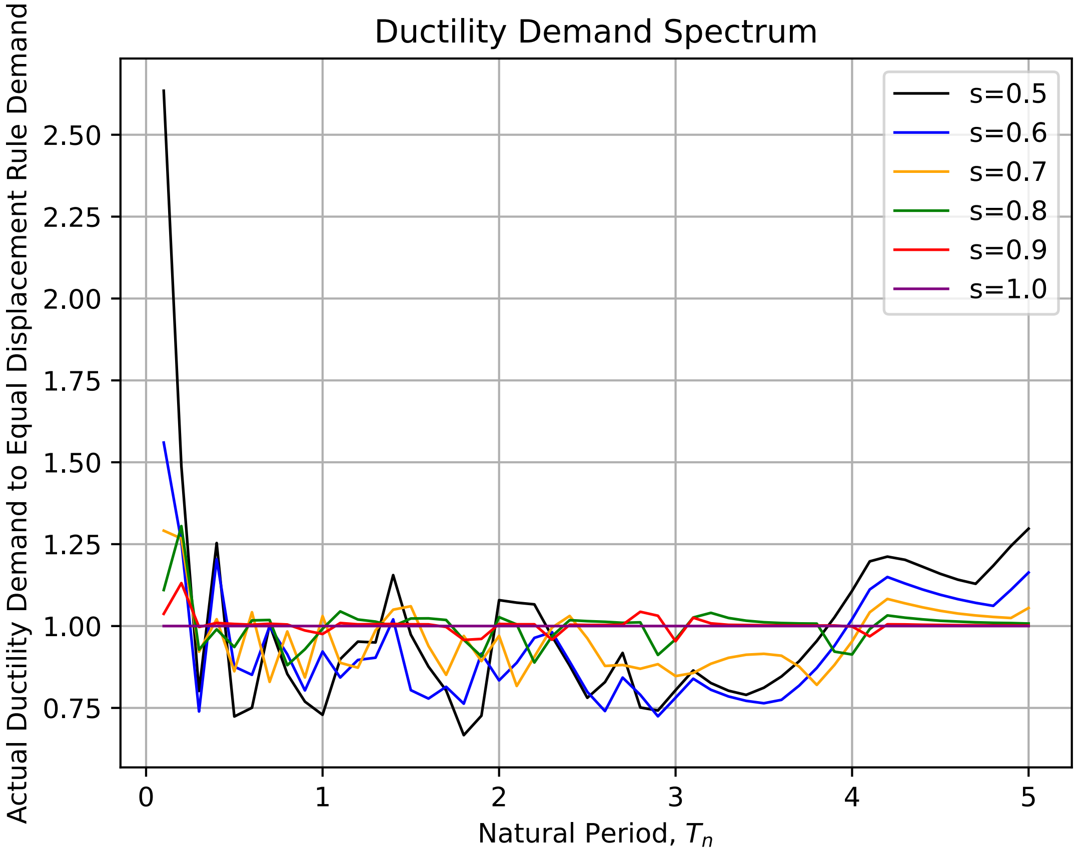
Reference: s=1 → $u_m = u_y$ → μ =1

El Centro

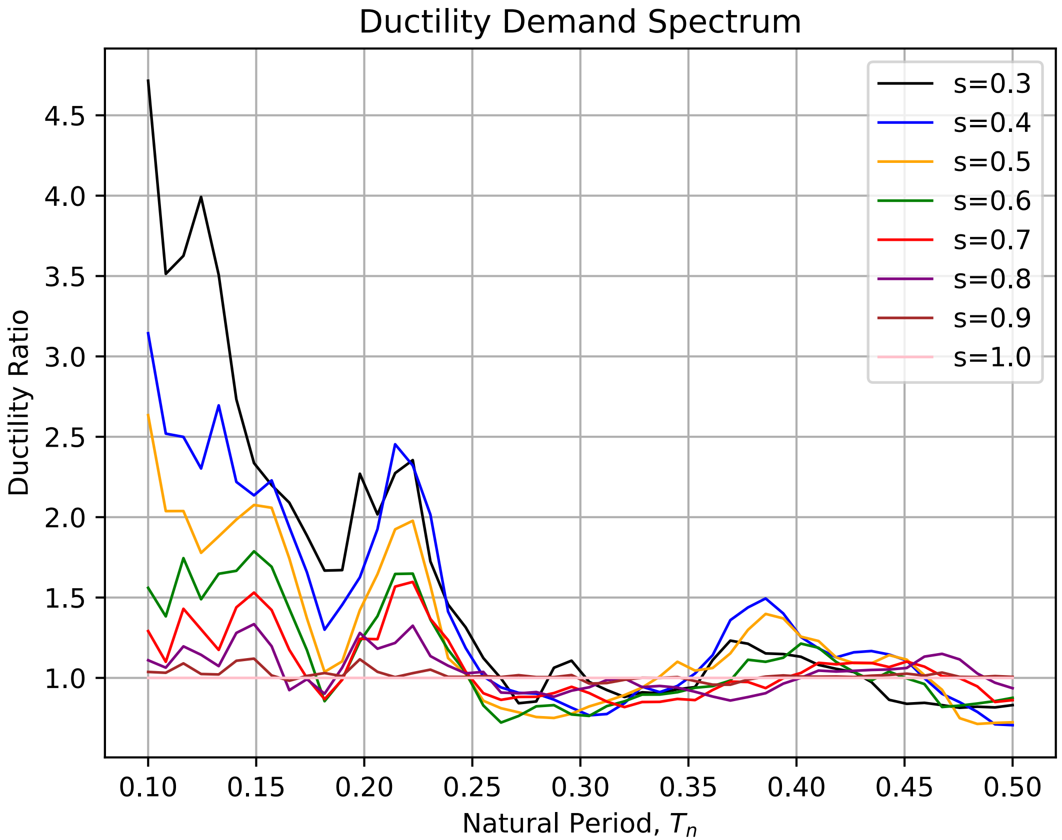

Ductility Demand ($T_n = 1.15 sec.$)
Actual ductility demand
Equal displacement rule
Ductility Demand
Relative Strength
0.2
0.4
0.6
0.8
1.0
2
4
6
8
10
12
14
16


Ductility Demand ($T_n = 1.15 sec.$)
Actual ductility demand
Equal displacement rule
Actual Ductility Demand
Equal Displacement Ductility
2
4
6
8
10
12
14
16

Ductility Demand Spectrum

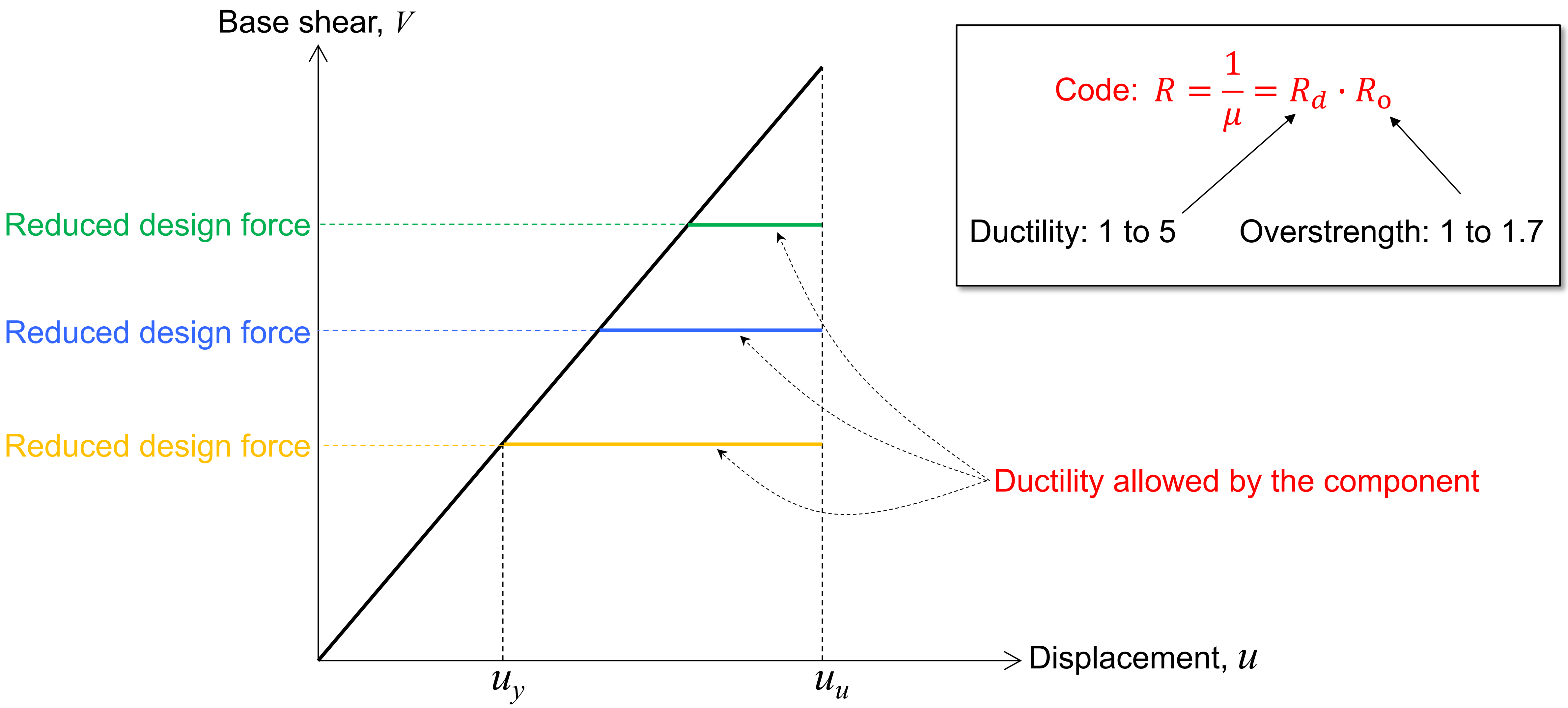


Careful with Low-rise Buildings

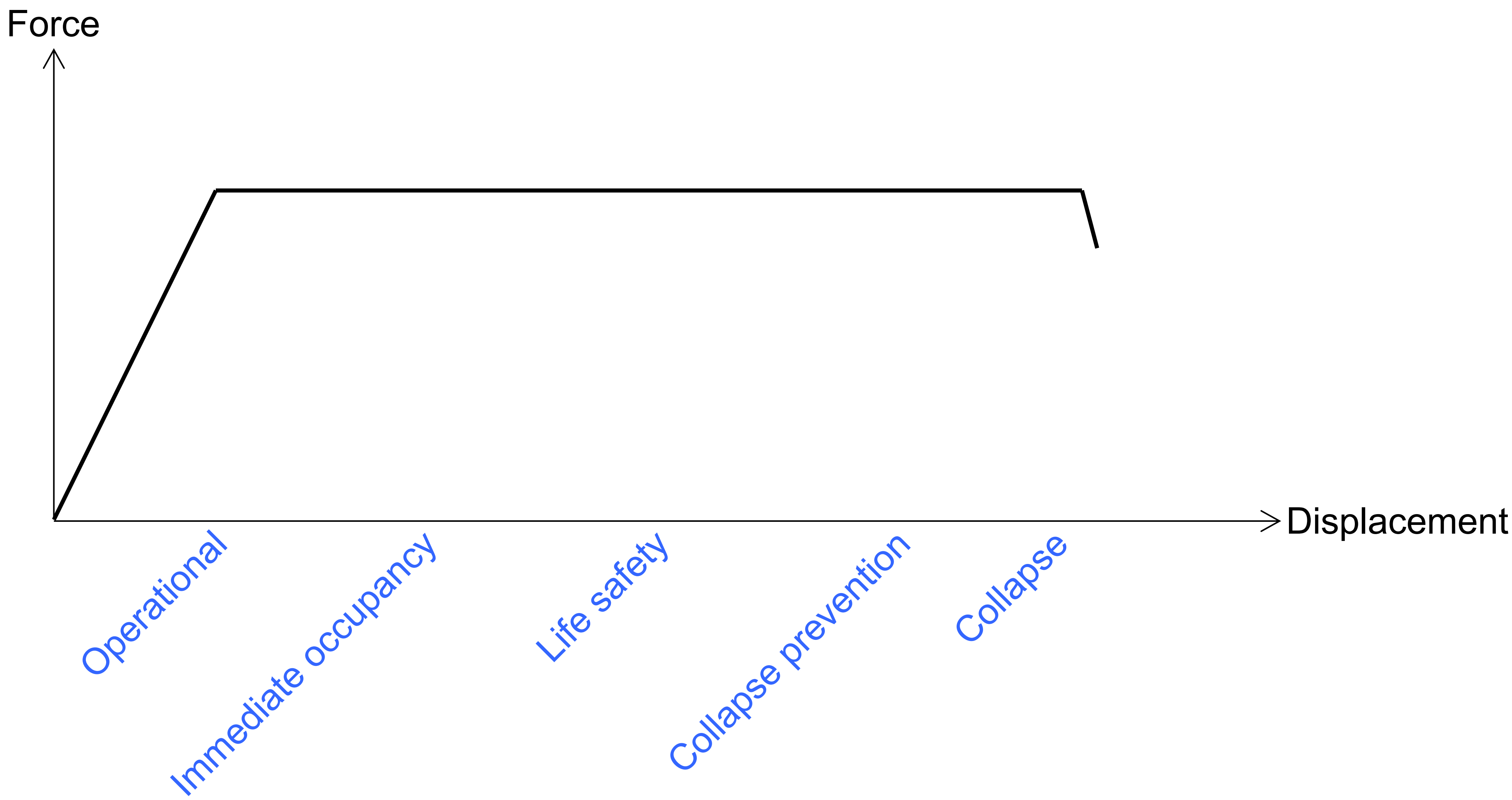


Force Reduction

If the equal displacement rule applies…



Performance



More lectures:

Terje’s Toobox:

terje.civil.ubc.ca