

ASCE 7-16 Provisions
Soil-Structure Interaction
State of the Standard & Research
Needs

January 28, 2015
SCEC Workshop

Soil-Structure Interaction

Foundation Force-Deformation

- > Foundation Flexibility
- > Soil-Foundation Interface Yielding

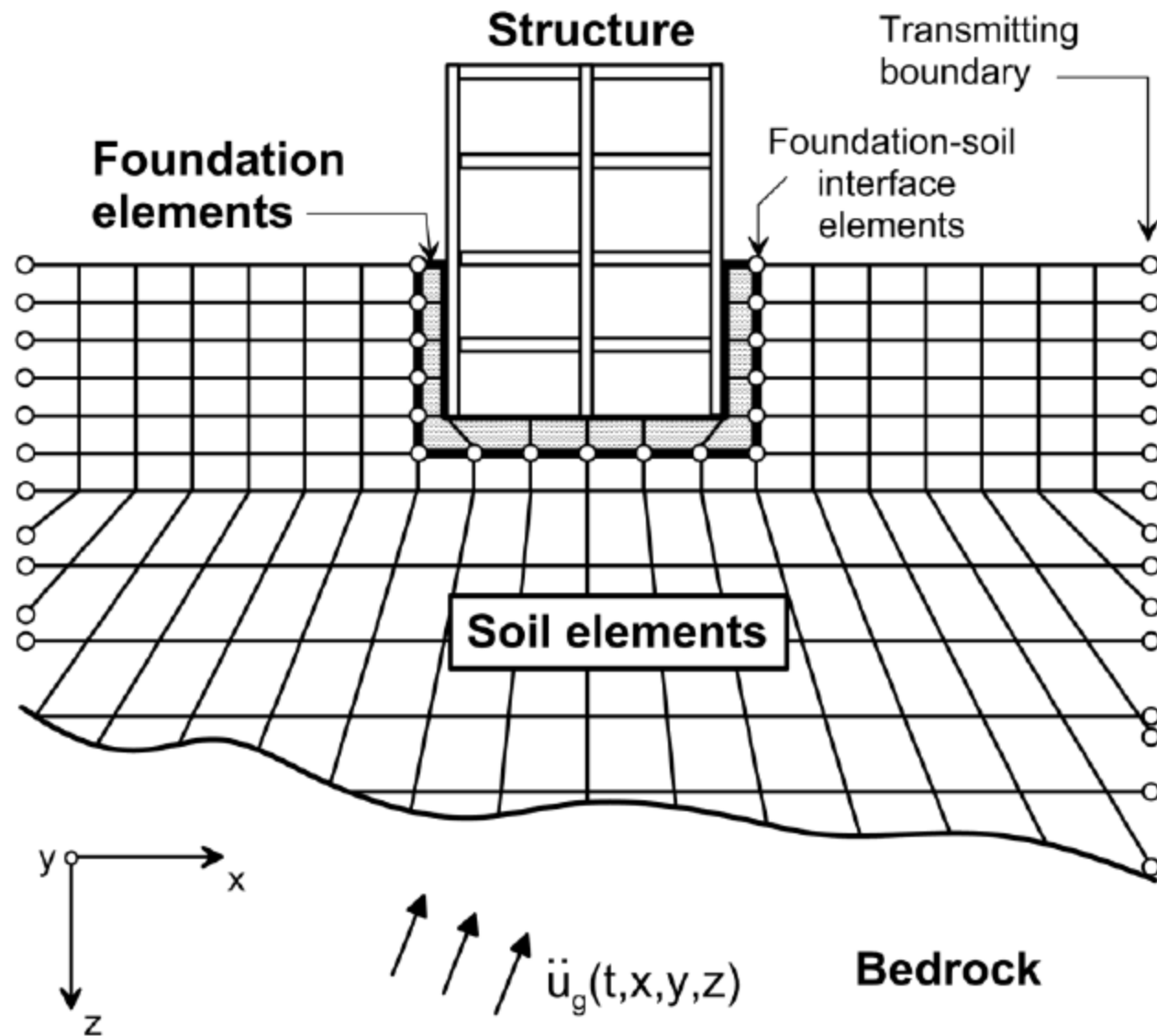
Foundation Damping

- > Radiation Damping
- > Soil Hysteretic Damping

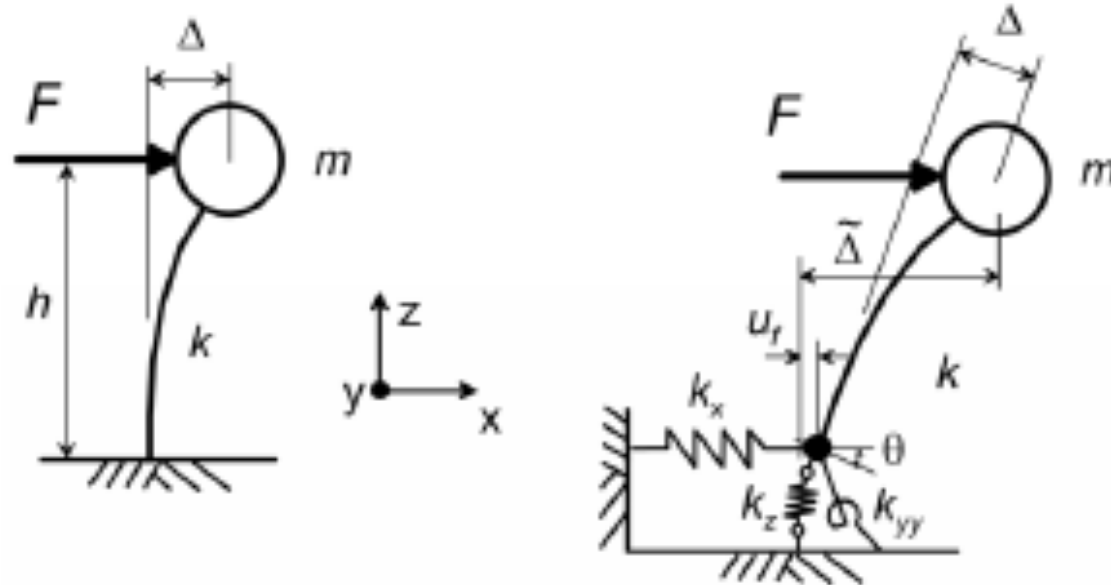
Kinematic Interaction

- > Base Slab Averaging
- > Embedment

What We Should Do



What We Actually Do



ASCE 7-10

Fixed-base modeling

ASD Foundation Design

Same “R” soil yielding as for
superstructure yielding

Only accounts for radiation
damping



ASCE 7-10

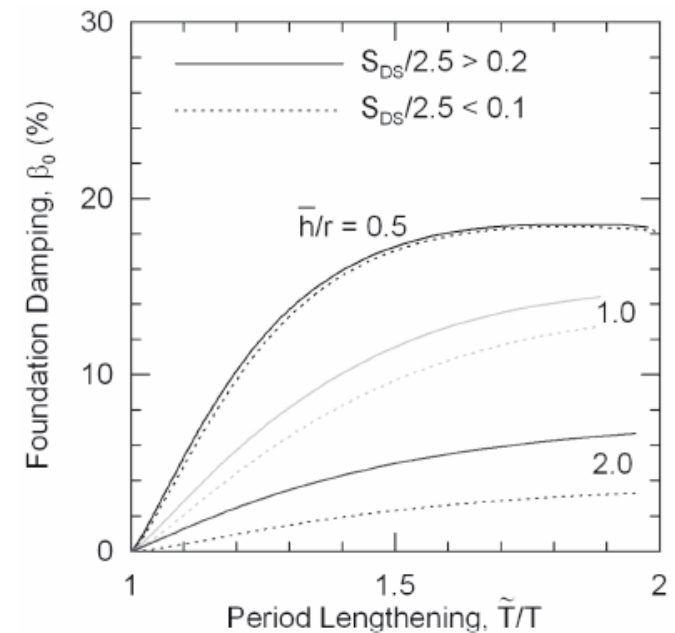
Reduce base shear, capped at 30%

$$\tilde{V} = V - \Delta V \quad \Delta V = \left[C_s - \tilde{C}_s \left(\frac{0.05}{\tilde{\beta}} \right)^{0.4} \right] \bar{W} \leq 0.3V$$

Theoretically based accounting for soil flexibility

$$\tilde{T} = T \sqrt{1 + \frac{25\alpha_r \bar{h}}{v_s^2 T^2} \left(1 + \frac{1.12 r_a \bar{h}^2}{\alpha_\theta r_m^3} \right)}$$

Theoretical soil damping relationships



ASCE 7-10

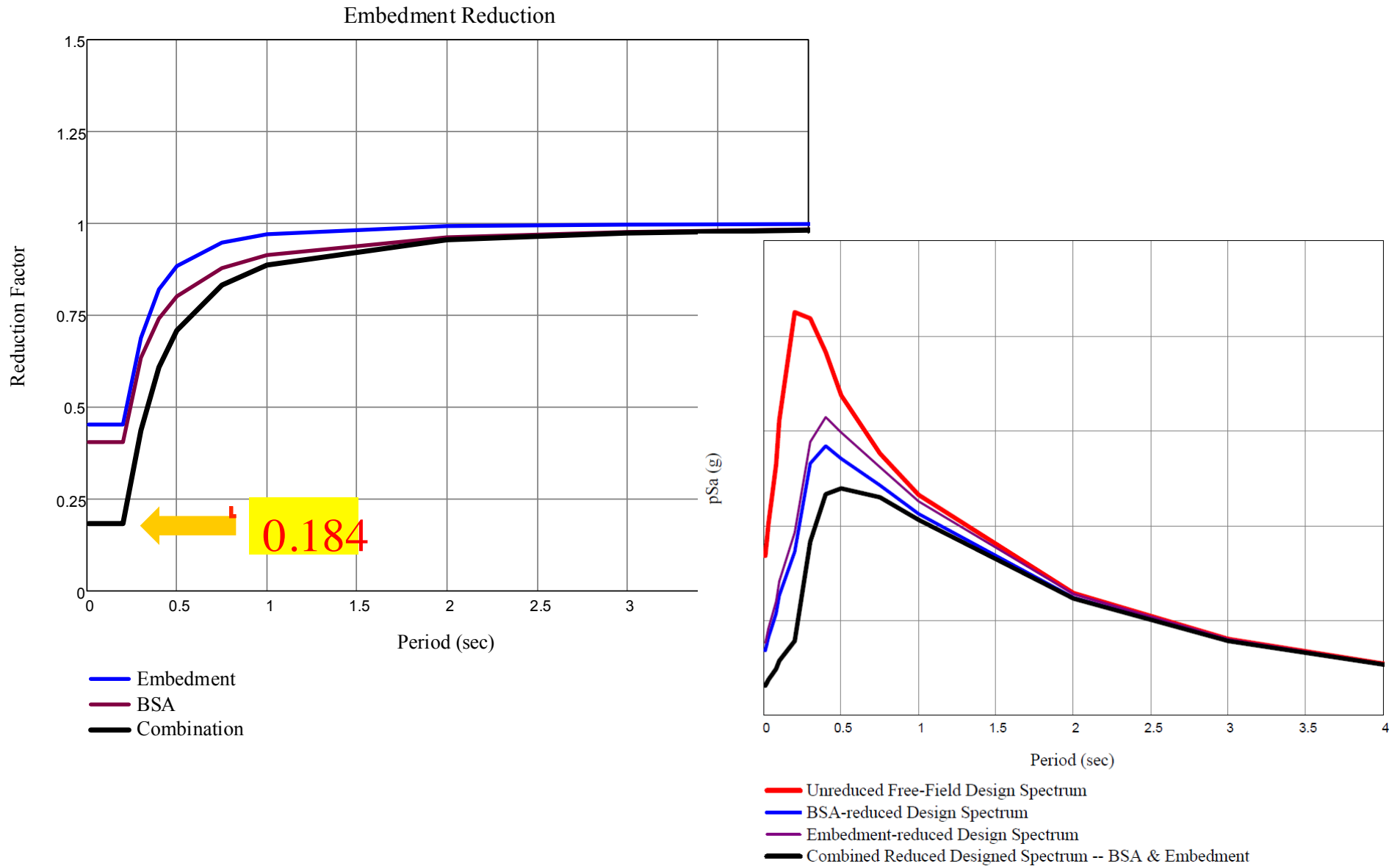
- Essentially unchanged from ATC 3-06
- Do not need to explicitly model the soil flexibility
- 2009 Provisions Commentary has guidance on how to incorporate explicit soil flexibility
- Equations cumbersome so not commonly used

ASCE 41-06

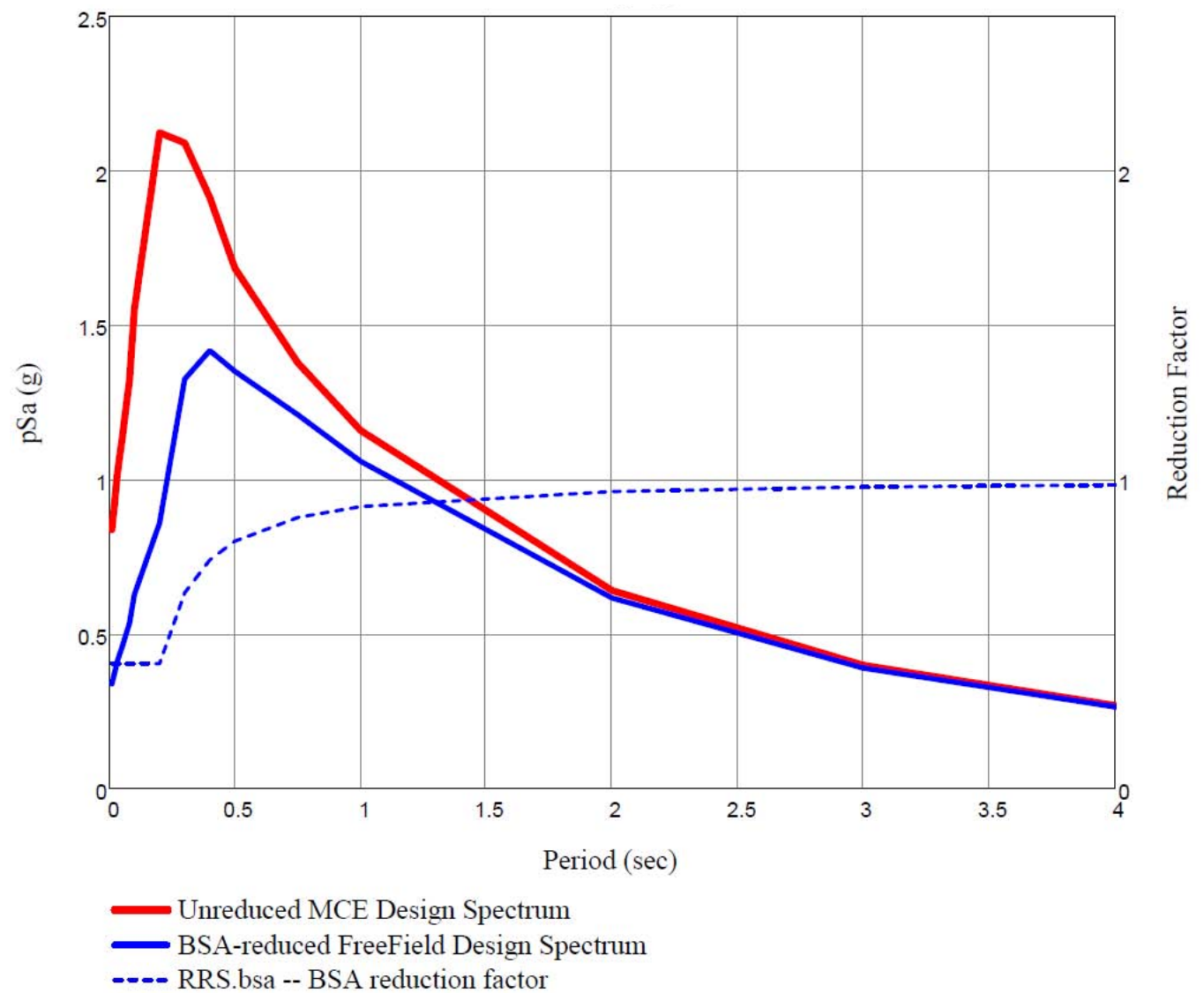
- Strength Foundation Design
- Provides Separate m-factor for the soil
- Requires foundation flexibility modeling for high performance
- Requires bounding soil properties
- Radiation Damping
- Base Slab Averaging
- Embedment Effects



Combined BSA & Embedment



Kinematic Interaction



ASCE 41-06

Concerns / Issues

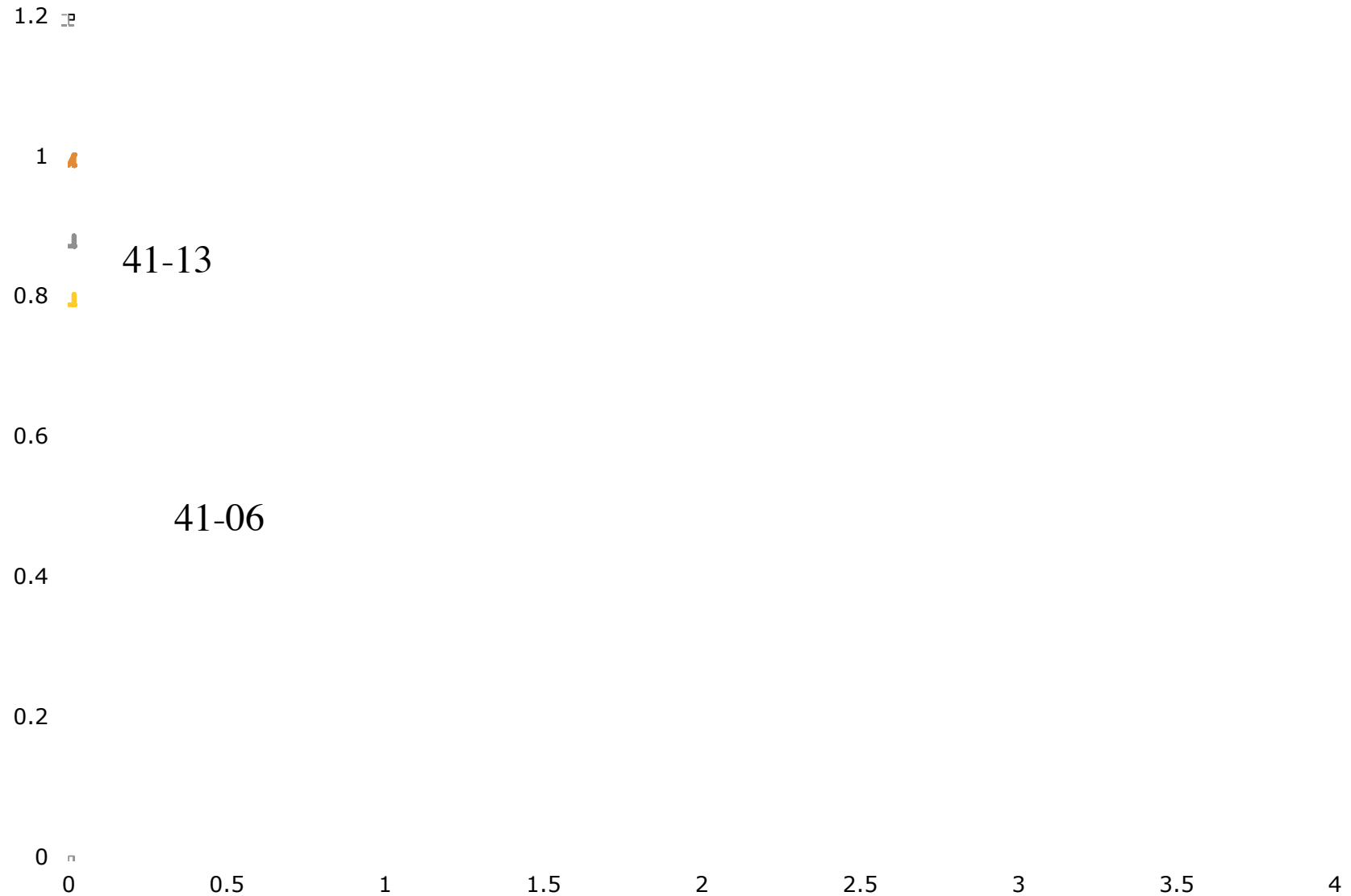
- Base slab averaging reduction is unlimited at short periods
- Base slab averaging equation predicts negative values at large base dimensions
- Embedment & base slab averaging can reduce PGA to 0.3 second values to $0.22 \times \text{Free Field}$
- Kinematic effects greatest at short periods, but no requirement to include foundation flexibility

ASCE 41-13

Issues to address

- Require soil flexibility modeled
- Provide overall kinematic limit of 50%
- Temper reductions for kinematic effects
- Limit base area for BSA
- Update equations for BSA

Soil-Foundation-Structure Interaction



Soil-Foundation-Structure Interaction

- > Base Slab Averaging & Embedment Equations Updated

$$RRS_{bsa} = 0.25 + 0.75 \times \left\{ \frac{1}{b_0^2} \left[1 - \exp(-2b_0^2) B_{bsa} \right] \right\}^{1/2} \quad B_{bsa} = \begin{cases} 1 + b_0^2 + b_0^4 + \frac{b_0^6}{2} + \frac{b_0^8}{4} + \frac{b_0^{10}}{12} & b_0 \leq 1 \\ \exp(2b_0^2) \left[1 - \frac{1}{\sqrt{\pi}b_0} \left(1 - \frac{1}{16b_0^2} \right) \right] & b_0 > 1 \end{cases}$$

- > Base area limited based on testing limits, 260 feet.

$$RRS_e = 0.25 + 0.75 \times \cos\left(\frac{2\pi e}{Tn v_s}\right) \geq 0.50$$

- > 0.75 factor reduces the reduction
- > Max reduction can only be 50%

2014 NEHRP Provisions

Issues to address

- Merger ASCE 41-13 Provisions with ASCE 7
- Direct inclusion of soil flexibility
- ATC-83 Report
- Update foundation damping equations
- Limitations on use

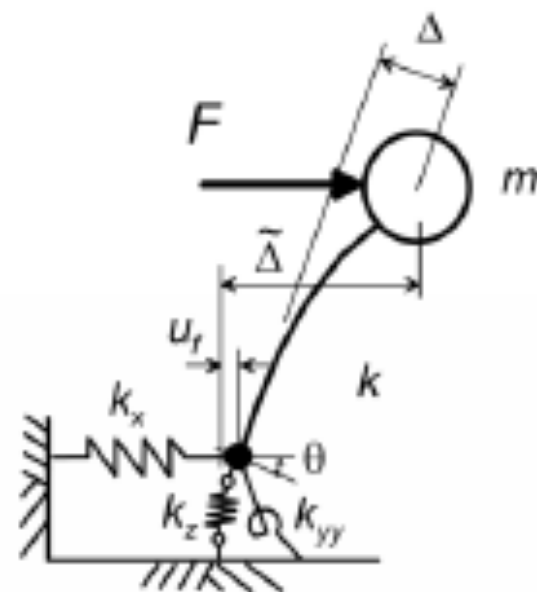
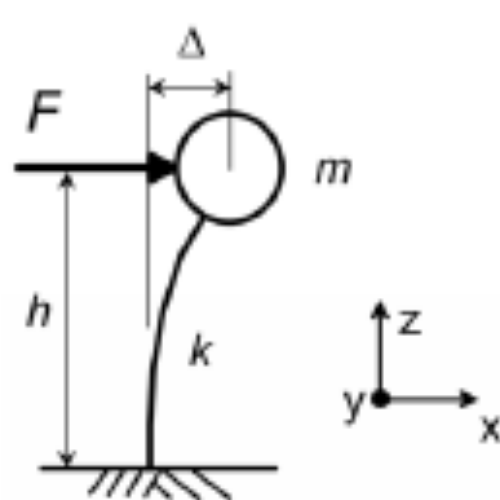
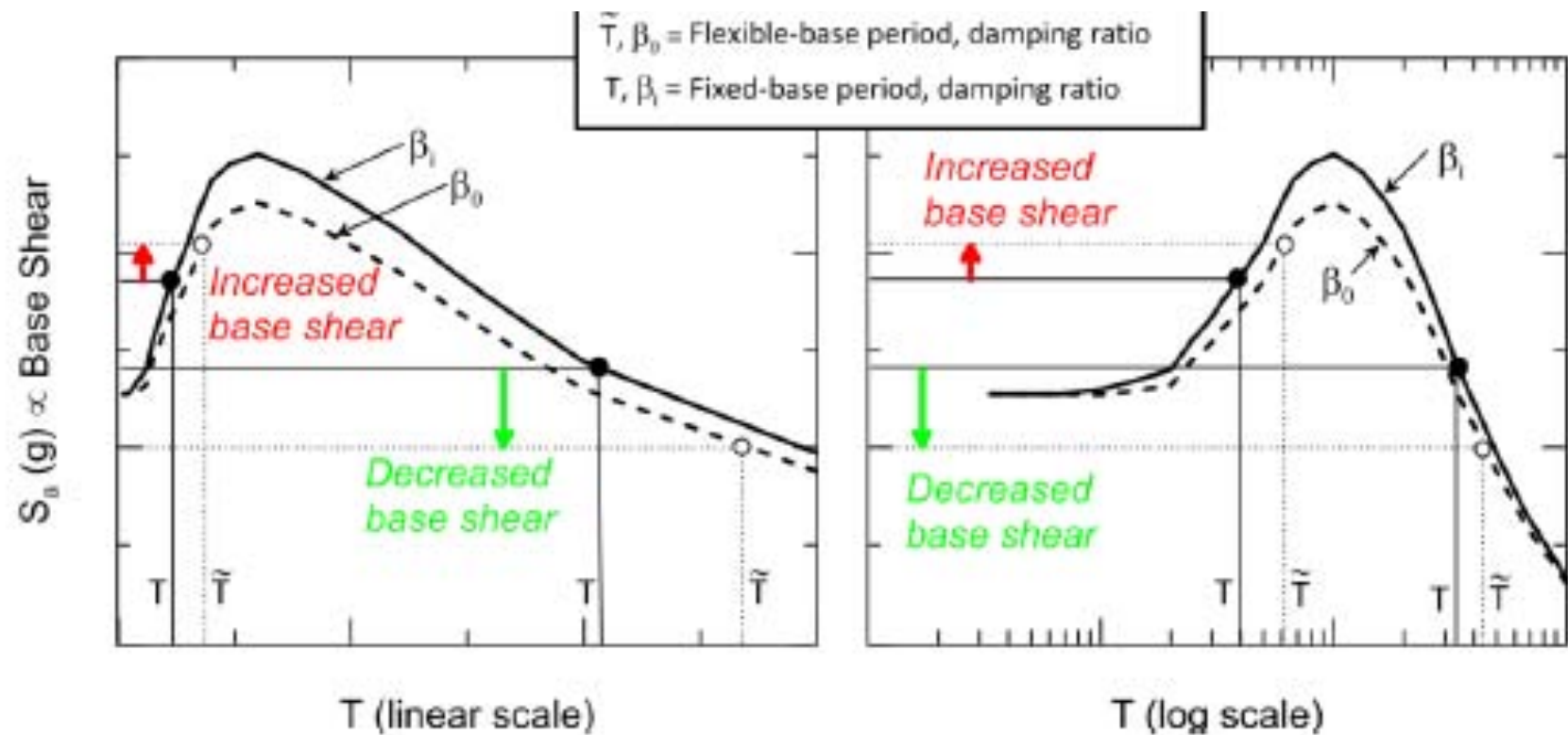
SSI & the R-Factor

“you get two for the dirt” – Henry Degenkolb

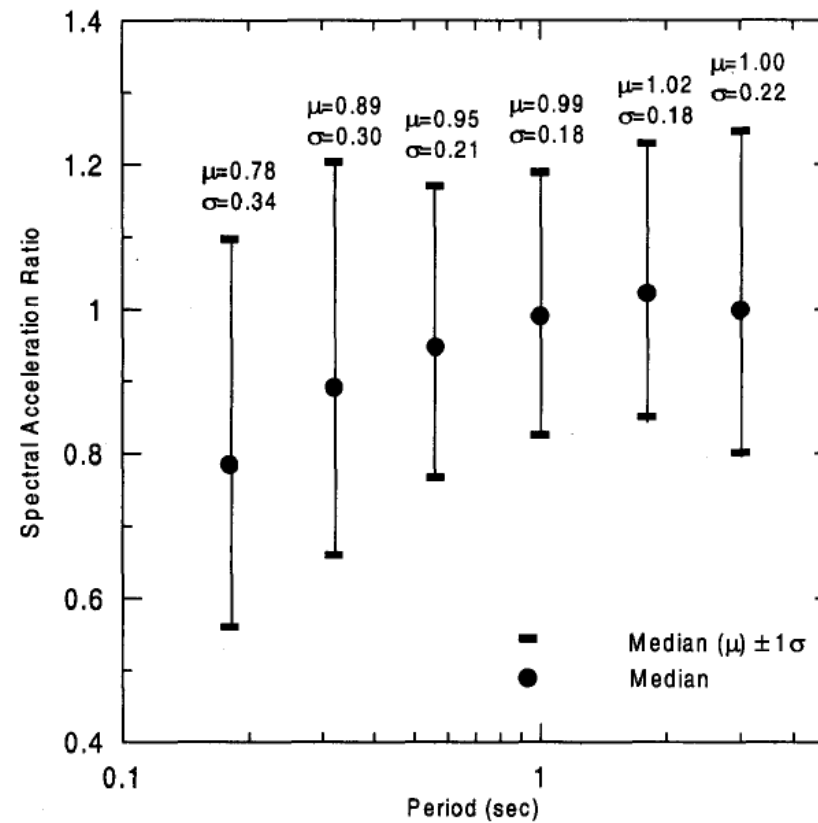
How much SSI is in the R-factor?

Currently limited to a 30% reduction

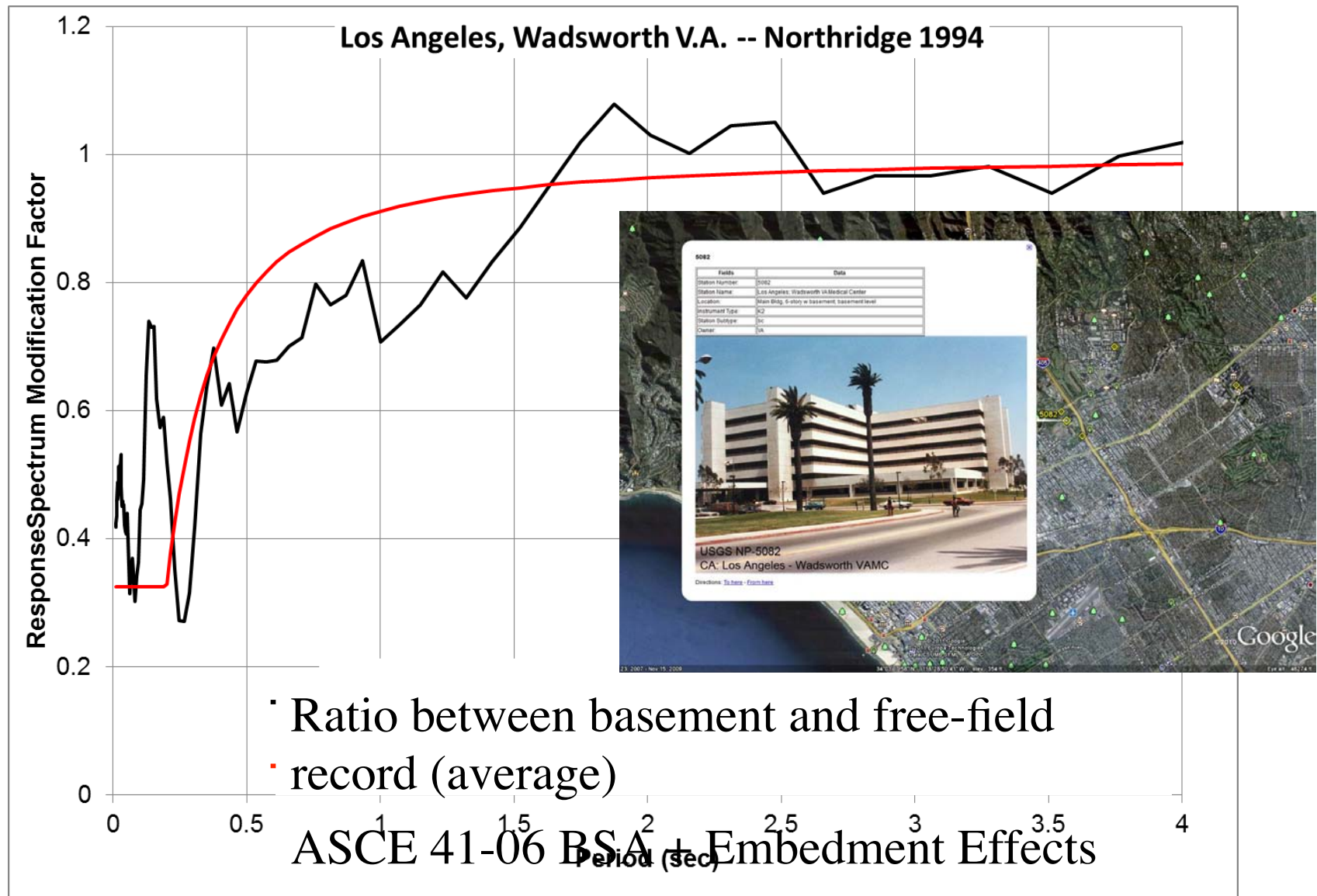
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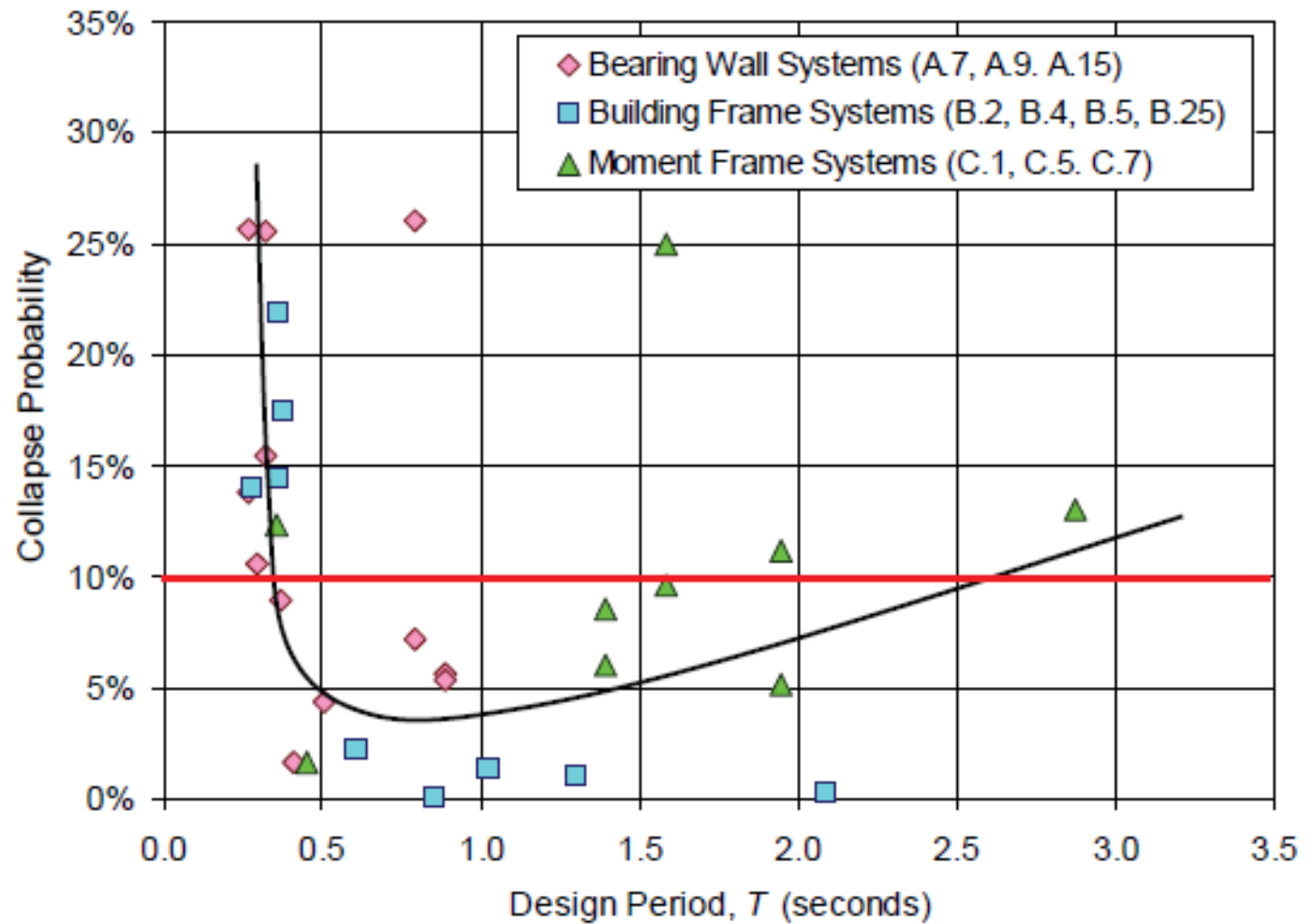
Scatter on Observed Data too Much



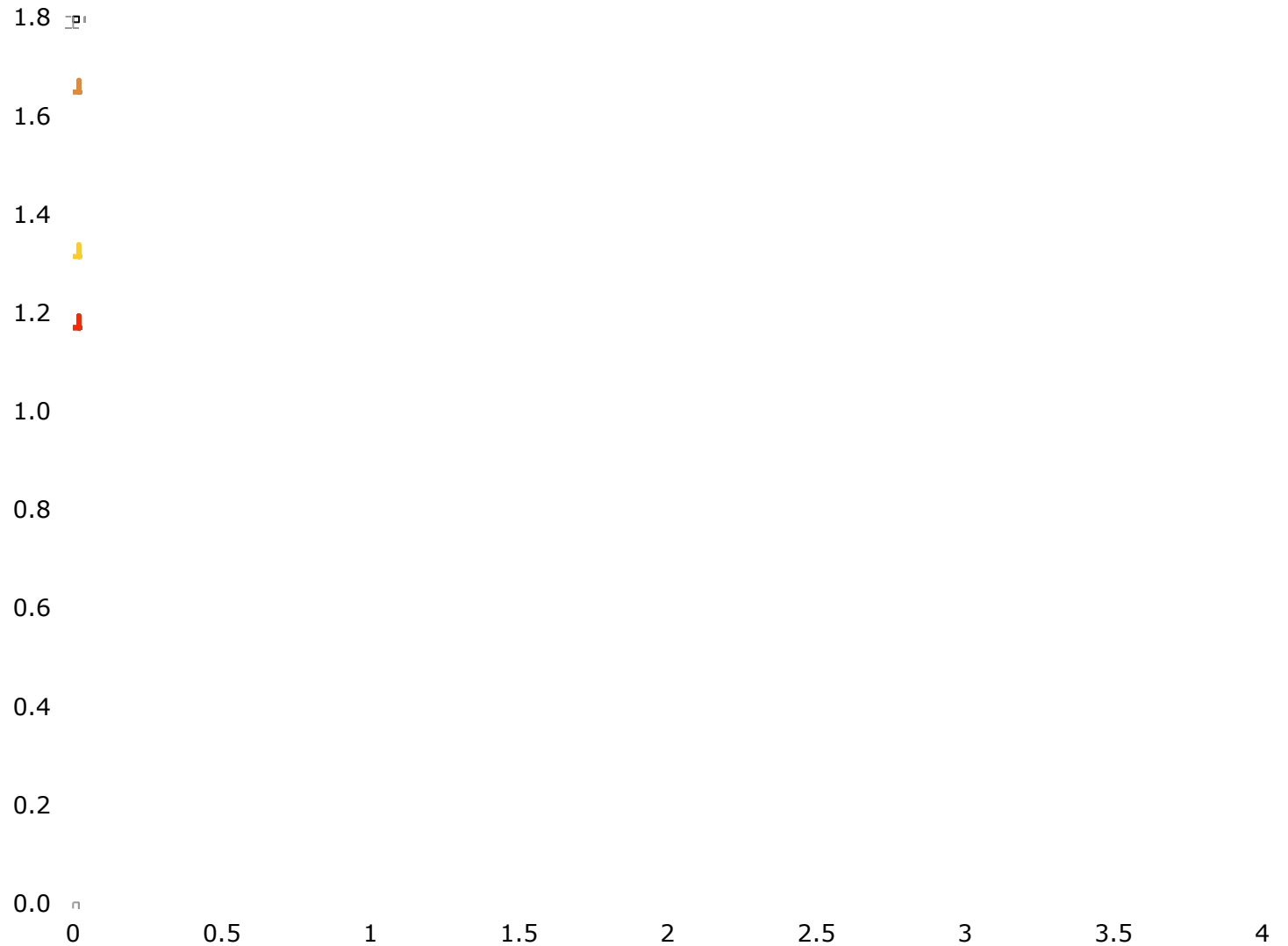
Look at Existing Data – Wadsworth Hospital



Short Period Issue?



Should SSI only be used with Site Specific Spectra?



2014 NEHRP Provisions

Foundation Damping

- Directly model flexibility at soil-foundation interface
- Updated radiation damping equations based on ATC-83
- Added a simplified table for Soil Damping
- Permissible reduction decreases with R-factor
 - 30% for $R < 3$ to only 10% for $R > 6$
- Use with NLRH only using explicit dashpots @ interface

2014 NEHRP Provisions

Kinematic Effects

- Limited to 20% reduction from site specific
- Limited to 30% reduction from USGS spectra
- Limited to 40% with peer review
 - 40% eliminated in ASCE 7-16
- Must model soil flexibility

2014 NEHRP Provisions

Foundation Load-Deformation

- Strength design of foundations passed
- Proposal to limit “R” at the soil interface failed

Research Needs

- Understanding interplay between kinematic, inertial, and structural yielding
- More examples from actual earthquakes validating SSI phenomena
- Better guidance on creating dashpots for NLRH models

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Thank You
Questions?

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