Effects of near-surface velocity profile, nonlinear model and input parameters in site response predictions
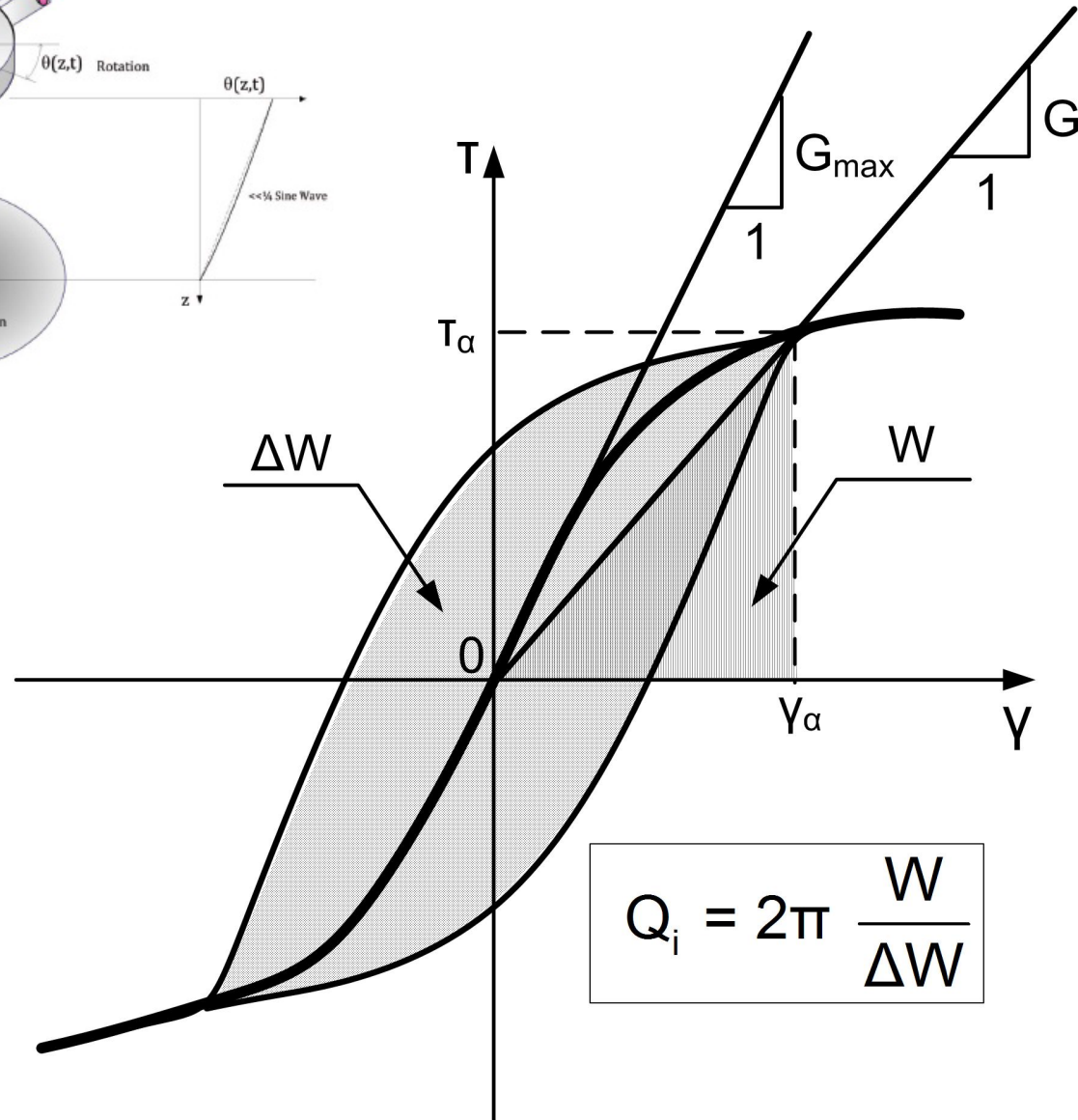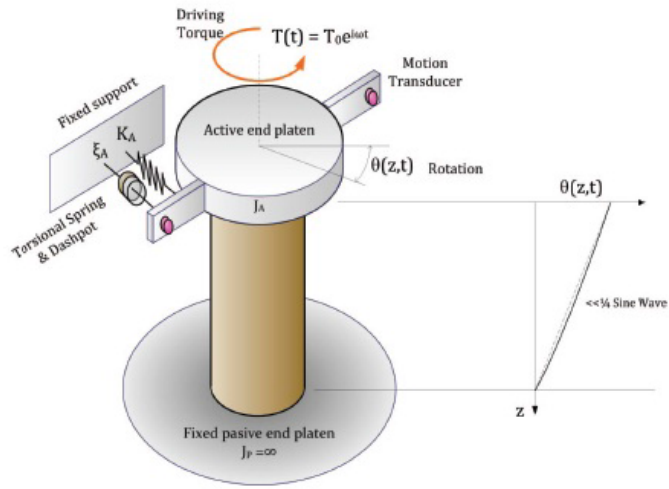
Carson Site s429 Case study

D. Asimaki
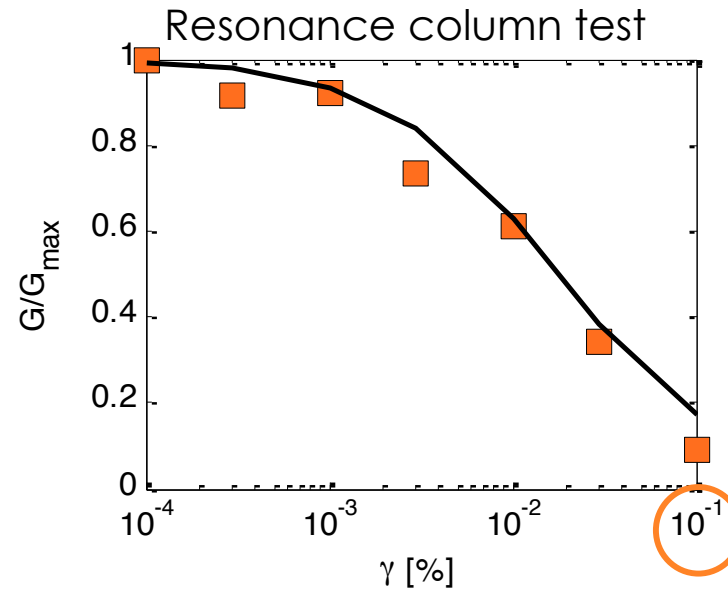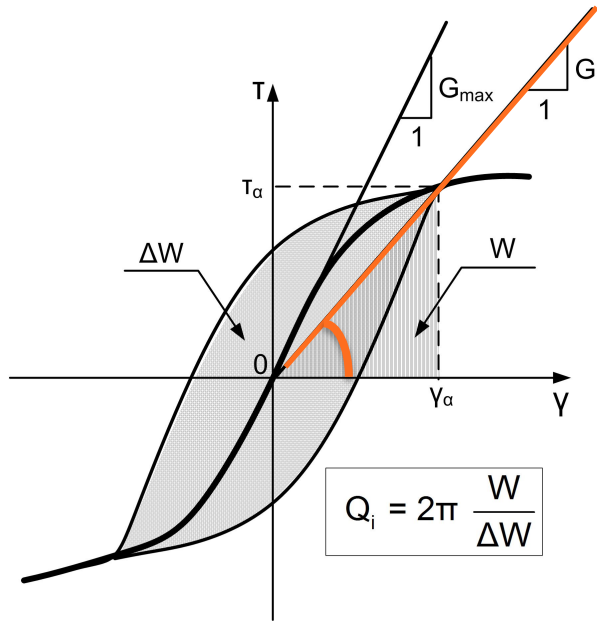
Mechanical and Civil Engineering
Caltech

Driving Torque $T(t) = T_0 e^{i\omega t}$

Motion Transducer

Fixed support

Active end platen

K_A

ξ_A

$\theta(z,t)$ Rotation

Torsional Spring & Dashpot

J_A

$\theta(z,t)$

<<¼ Sine Wave

z

Fixed pasive end platen
$J_P = \infty$

T

G_{max}

$\dfrac{G_{max}}{1}$

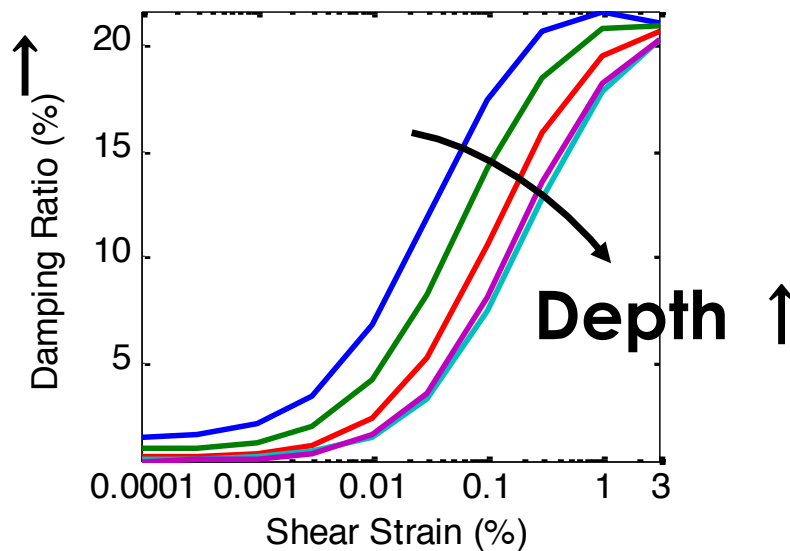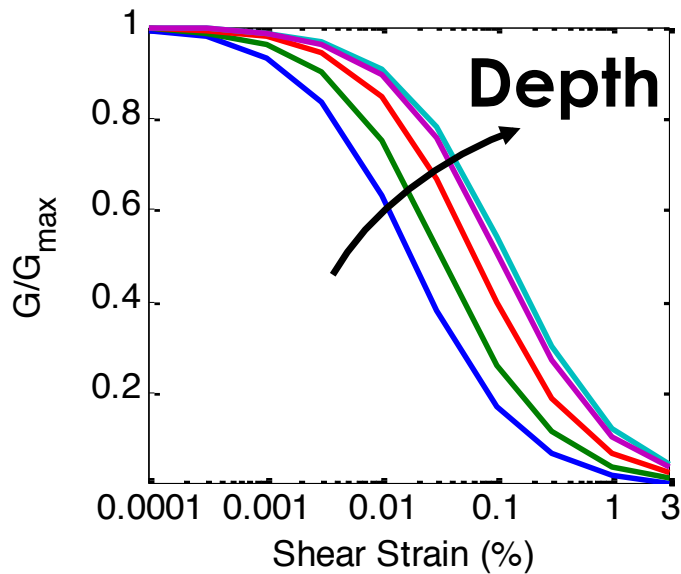$\dfrac{G}{1}$

T_α

ΔW

W

0

γ_α

γ

$$Q_i = 2\pi \ \frac{W}{\Delta W}$$

Nonlinear soil behavior in cyclic loading
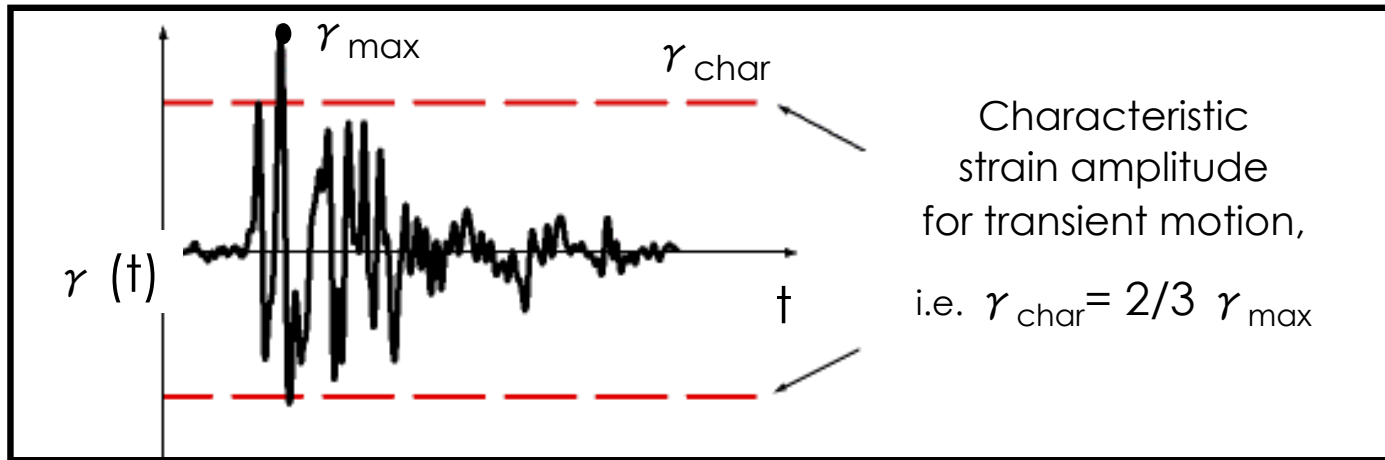

$$Q_i = 2\pi \frac{W}{\Delta W}$$

Resonance column test

Nonlinear soil behavior in cyclic loading
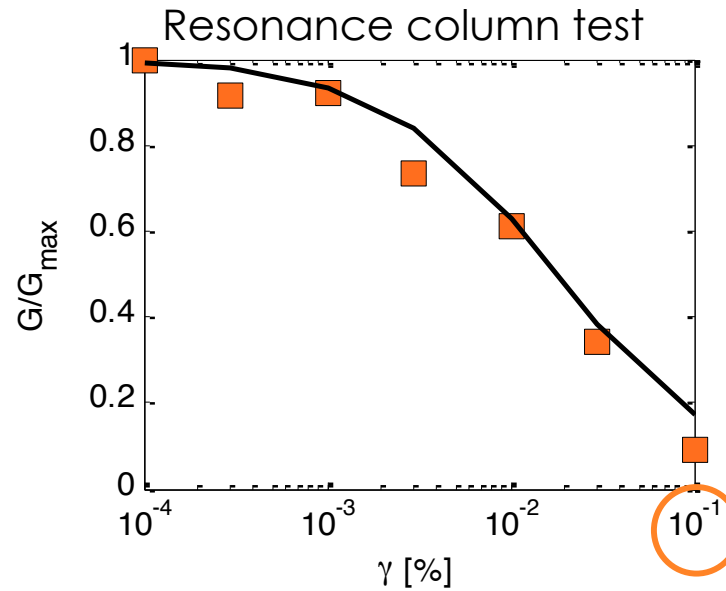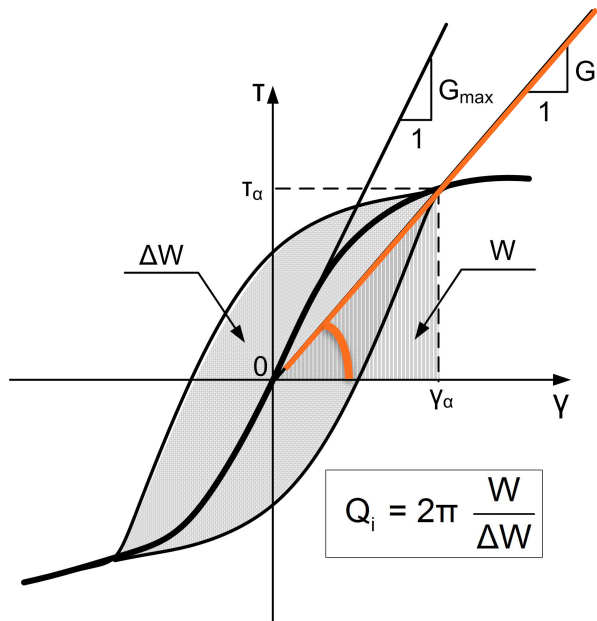
Equivalent Linear Site Response

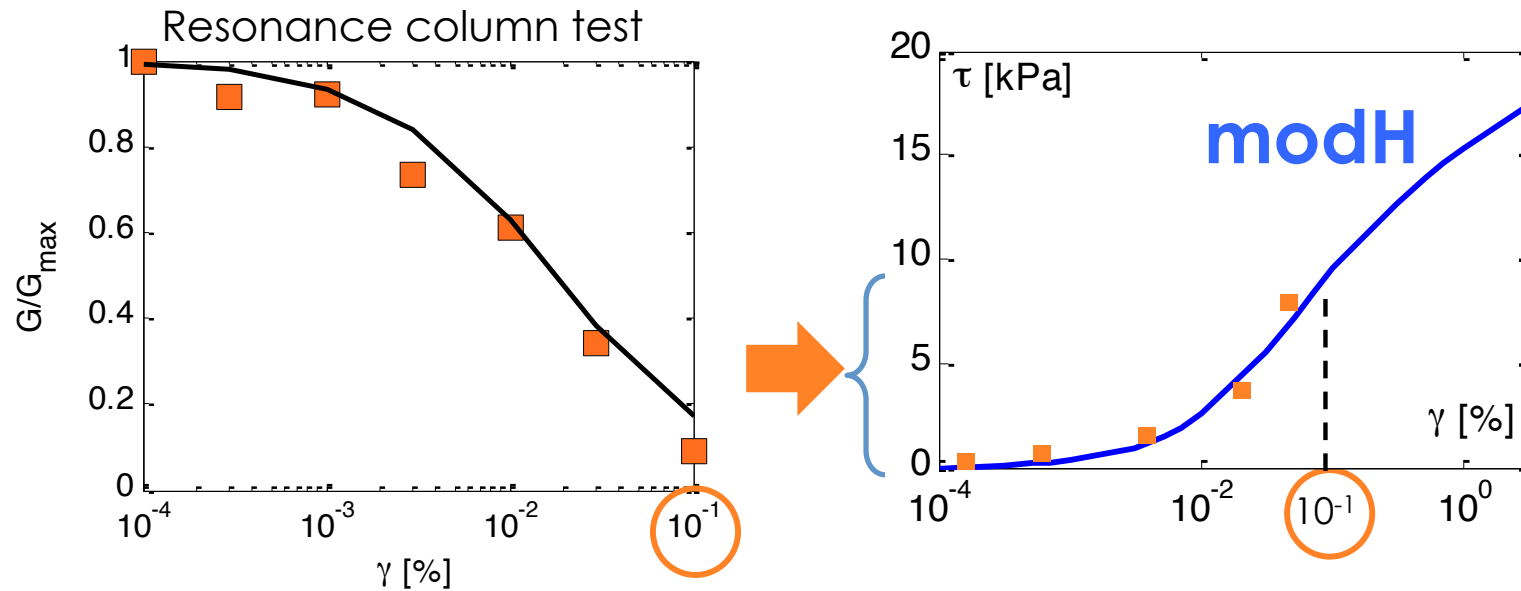Iteration i : Estimate characteristic level of strain γ_{char}^{i}

γ_{max}

γ_{char}

$\gamma(t)$

t

Characteristic strain amplitude for transient motion,

i.e. $\gamma_{char} = 2/3\ \gamma_{max}$

Iterate until convergence

Iteration i +1: Select G/G_{max} and ξ consistent with γ_{char}^{i}

1.0

0.5

0

$G/G_{max}^{(i+1)}$

$\gamma_{char}^{(i)}$

10^{-6} 10^{-4} 10^{-2} 1

0.4

0.3

0.2

0.1

0

$\xi^{(i+1)}$

$\gamma_{char}^{(i)}$

10^{-6} 10^{-4} 10^{-2} 1
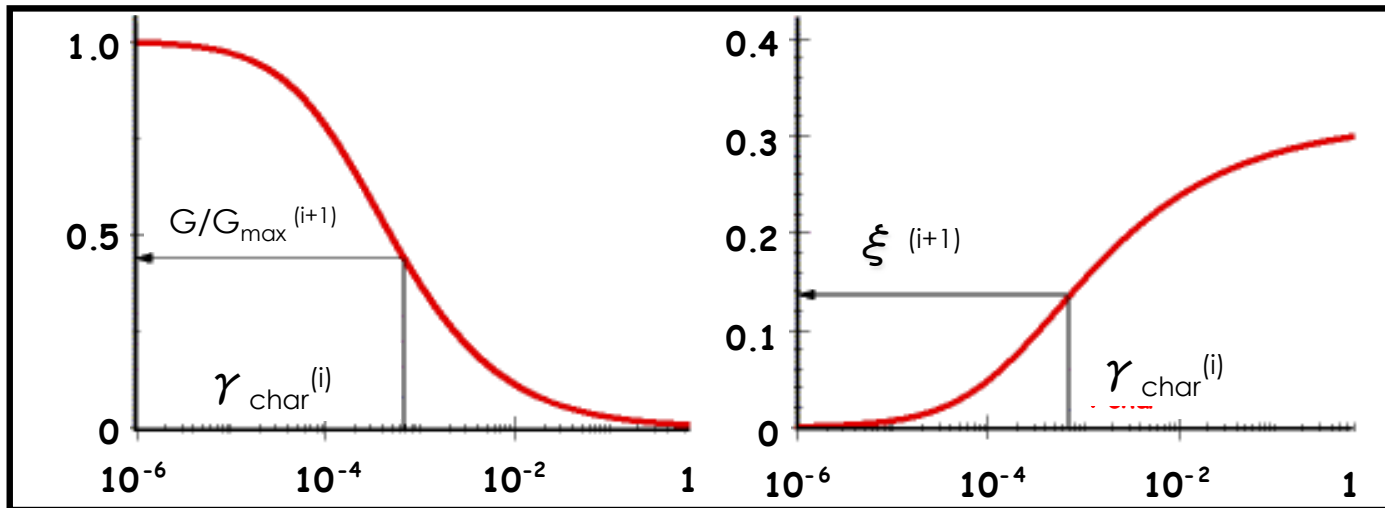
(Schnabel et al, 1972)

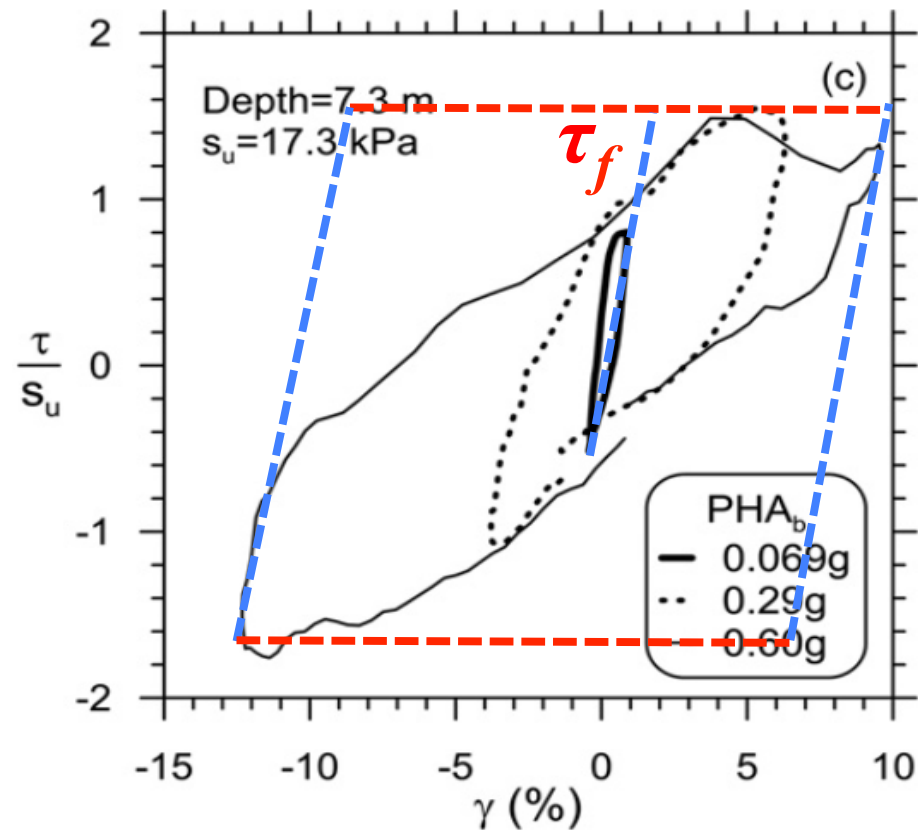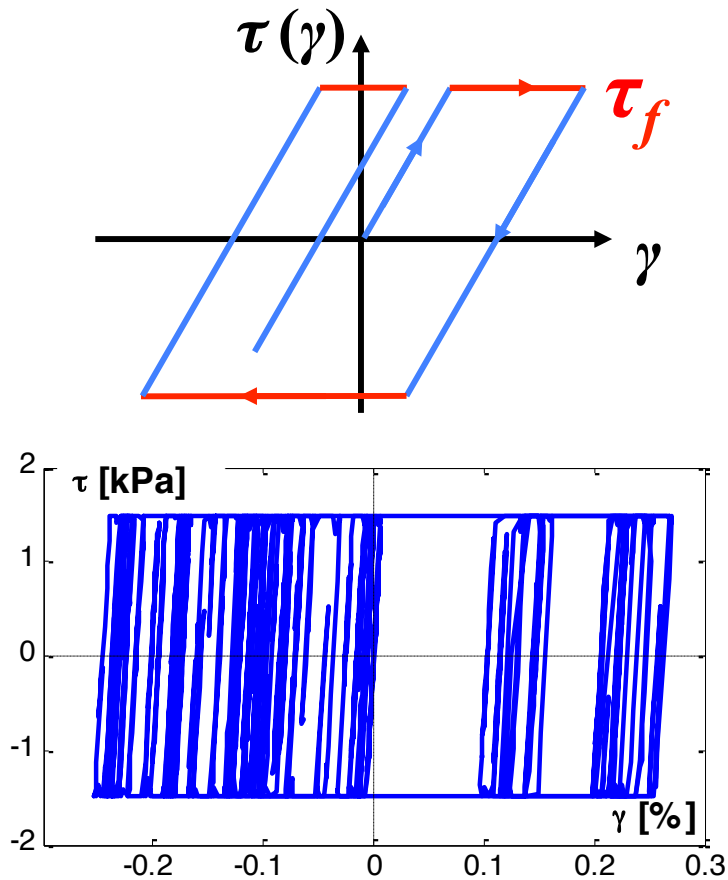# Nonlinear soil behavior in cyclic loading

How well does modH predict large strains?

$$\lim_{\gamma \to +\infty} \tau(\gamma) = \lim_{\gamma \to +\infty} \frac{G_{max} \cdot \gamma}{1 + \beta \left(\dfrac{\gamma}{\gamma_{ref}}\right)^s} \to \boxed{+\infty}$$
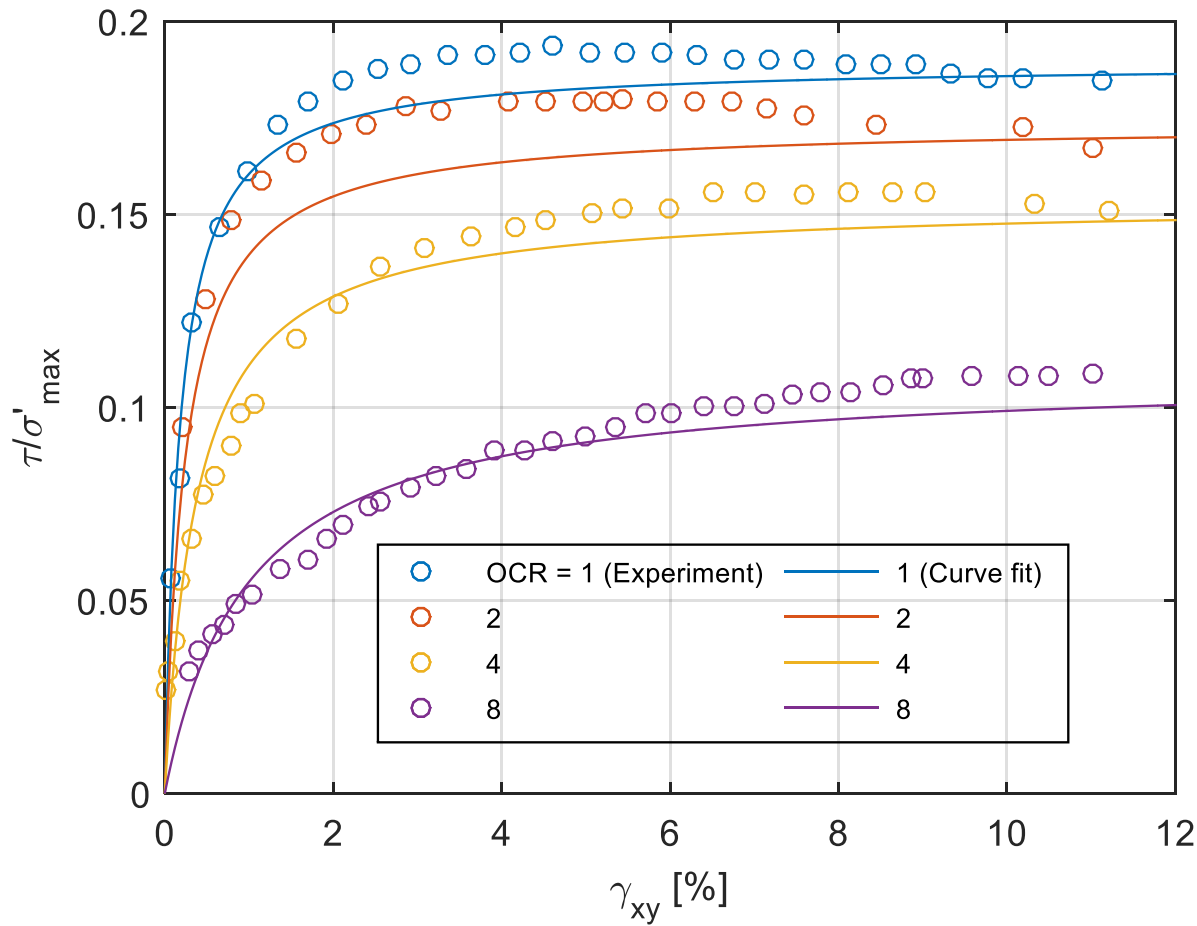
Plasticity models calibrated for strength

Elastic-perfectly-plastic (EPP) simulating laboratory experiments

(e.g. *Roten et al.*, 2014; *Tarboda et al.*, 2013)   (e.g. *Afacan, Brandenberg & Stewart*, 2013)

Hybrid stress-strain model: Strength

Direct simple shear test (from Ladd & Edgers, 1972)

Nonlinear site-specific response = function of V_s

$$\tau_{HY}(\gamma) = w(\gamma) \times \tau_{MKZ}(\gamma) + [1 - w(\gamma)] \times \tau_{\mu KZ}(\gamma)$$

Nonlinear optimization to achieve smoothness

Darendeli (2001)

Ladd (1991), Mayne et al (1996, 1998) Vardanega & Bolton (2011)

V_s profile

Ladd & Edgers, 1972
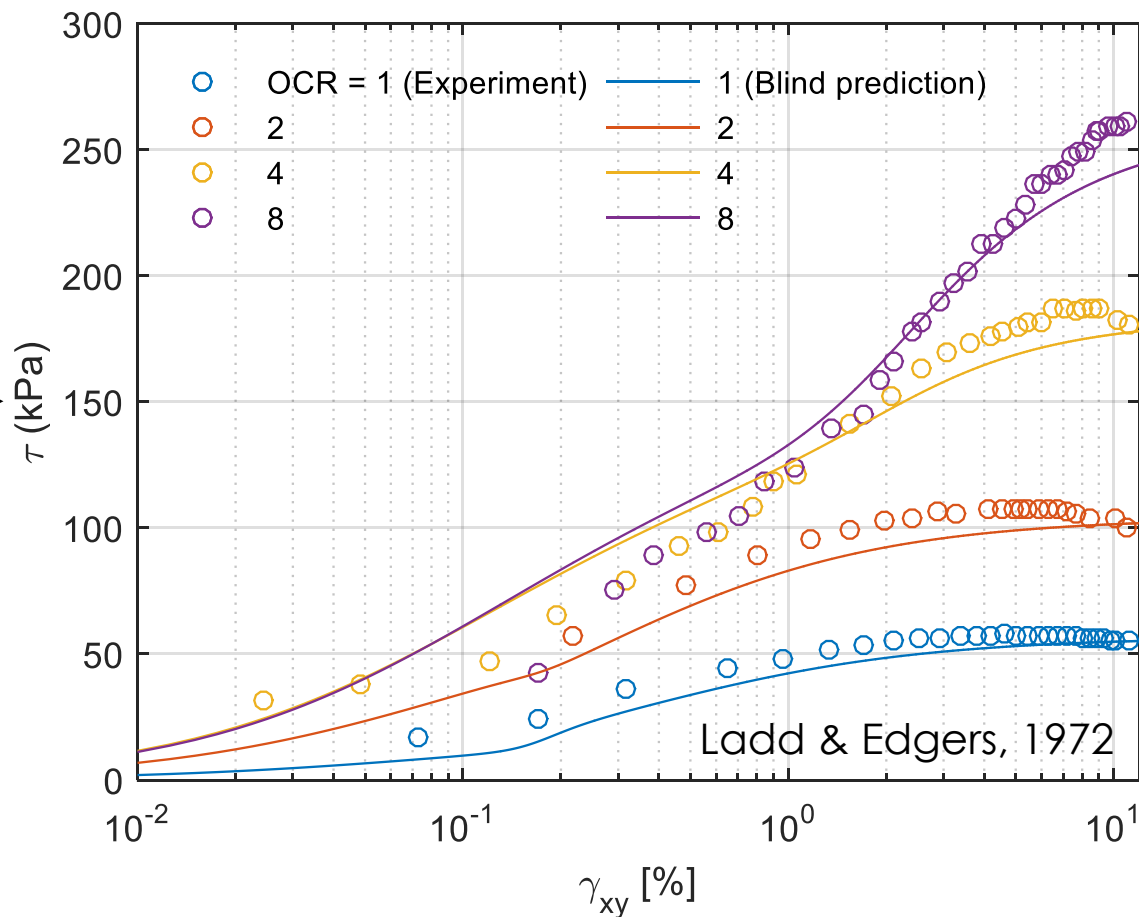
Vs Profiles. Carson Site, s429
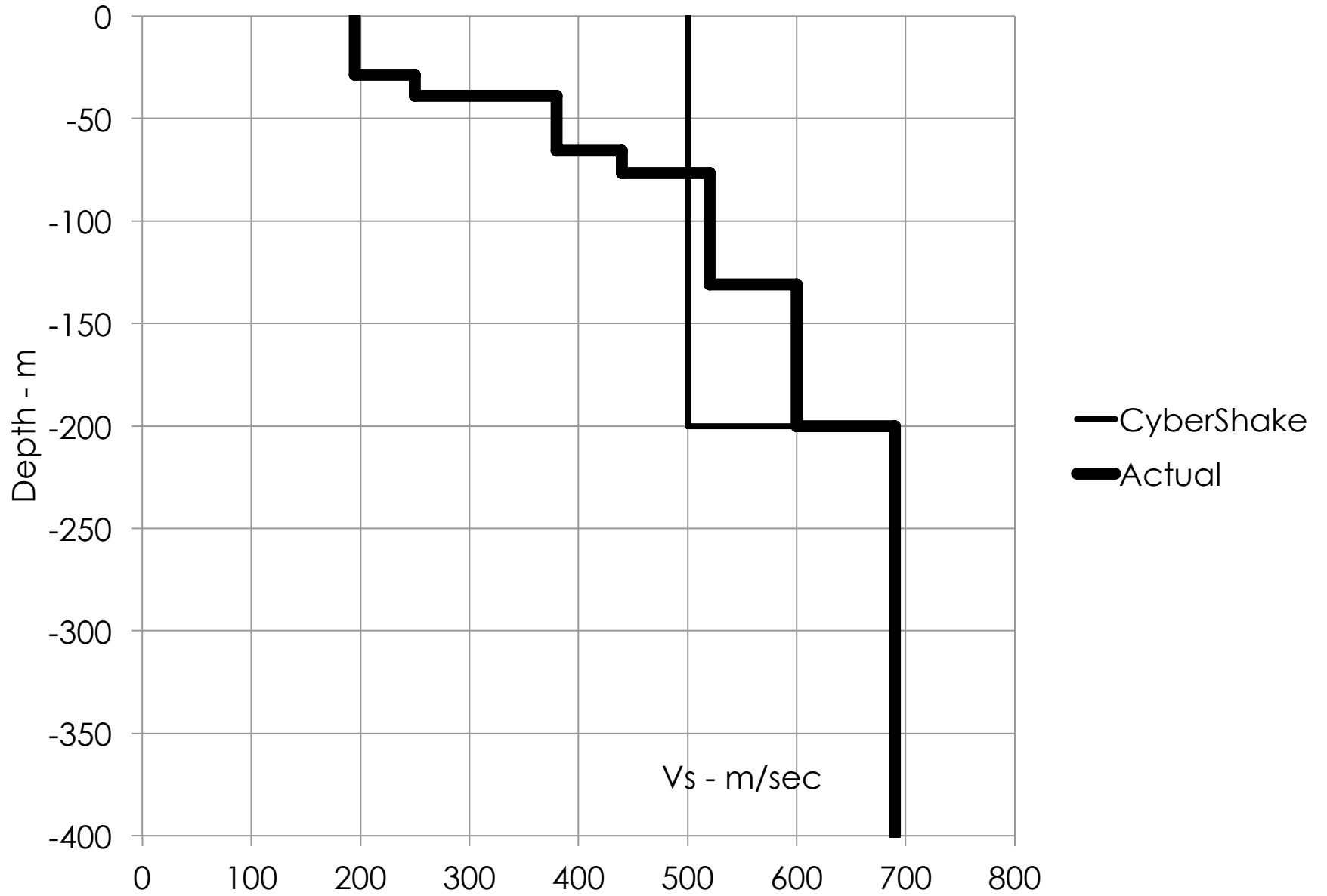
1978 Tabas, Iran, Free Field Accelerations
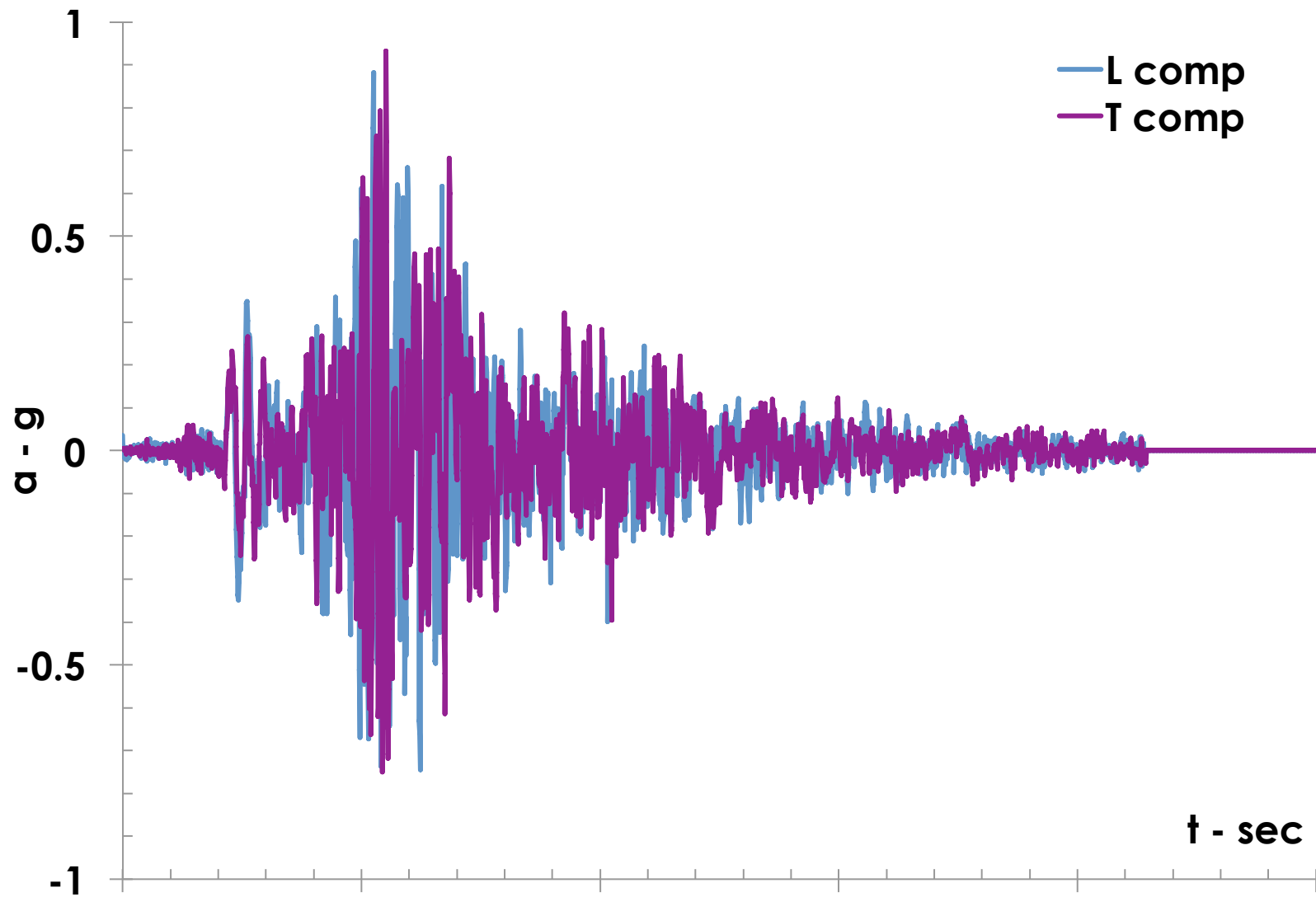
Cybershake Profile

Response Spectra: Scale Factor 1.0

Site-Specific Profile: EQ constant vs depth dependent G/G0 (L)
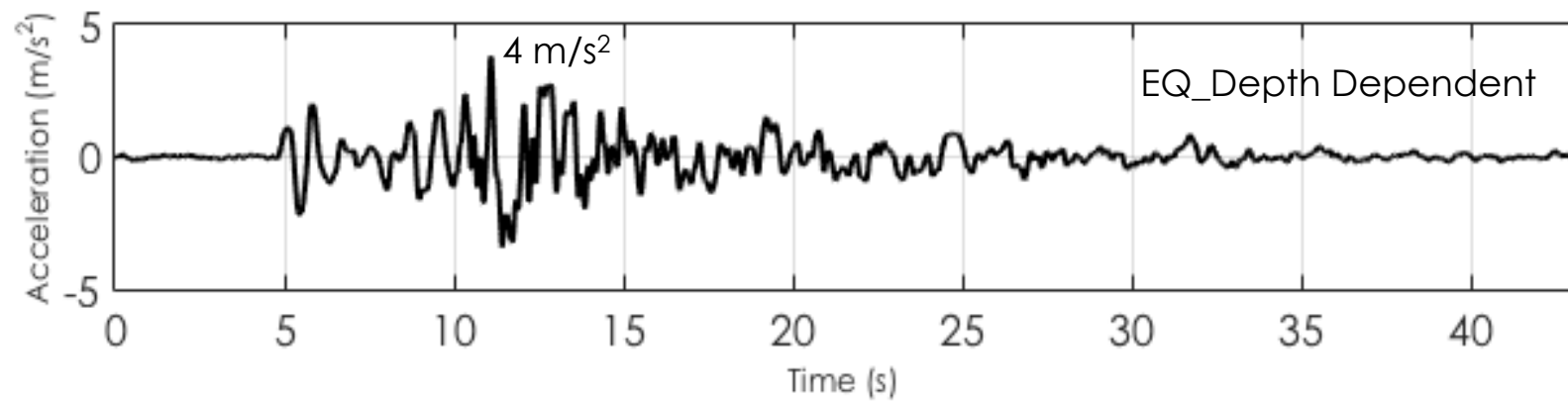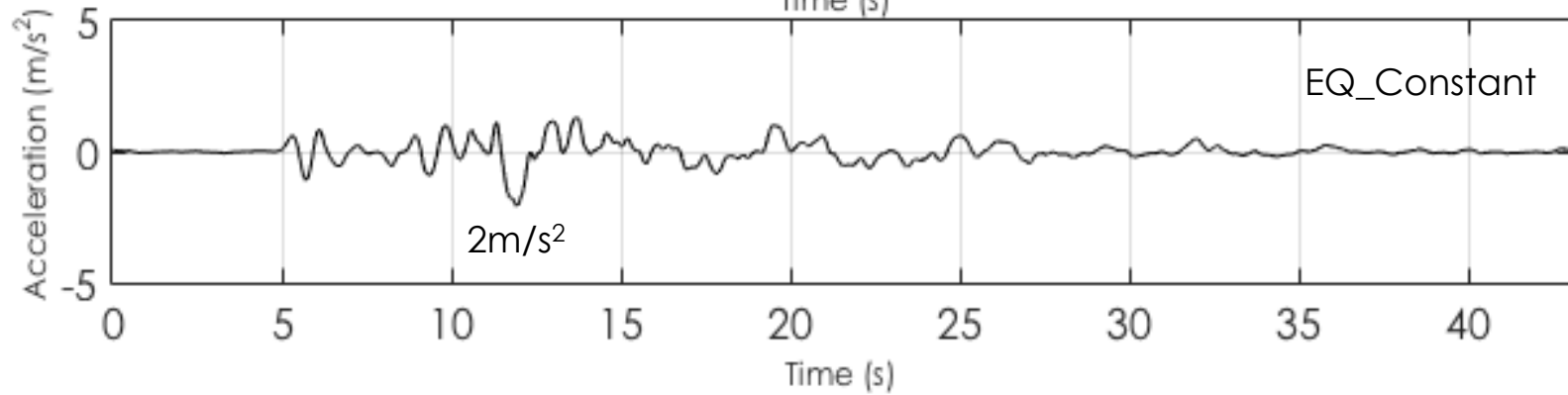
Site-Specific Profile: Depth dependent G/G0 EQ vs NL constant (L)
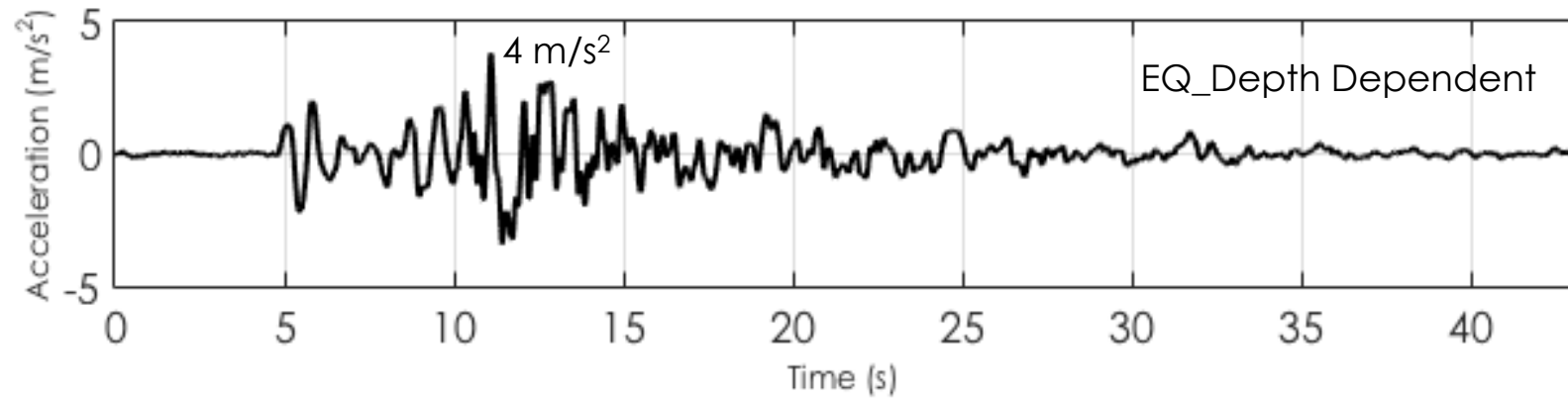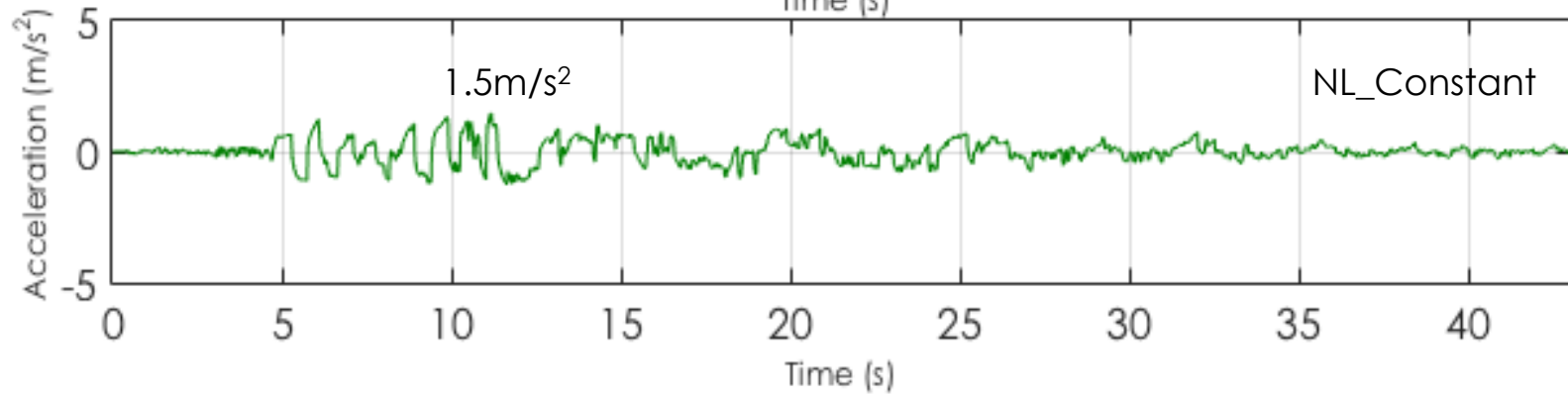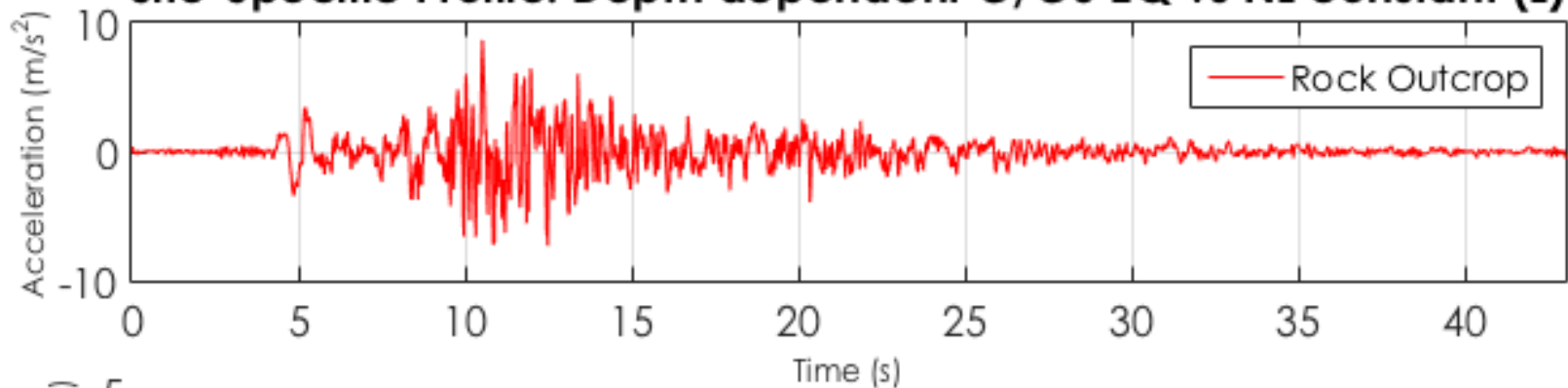
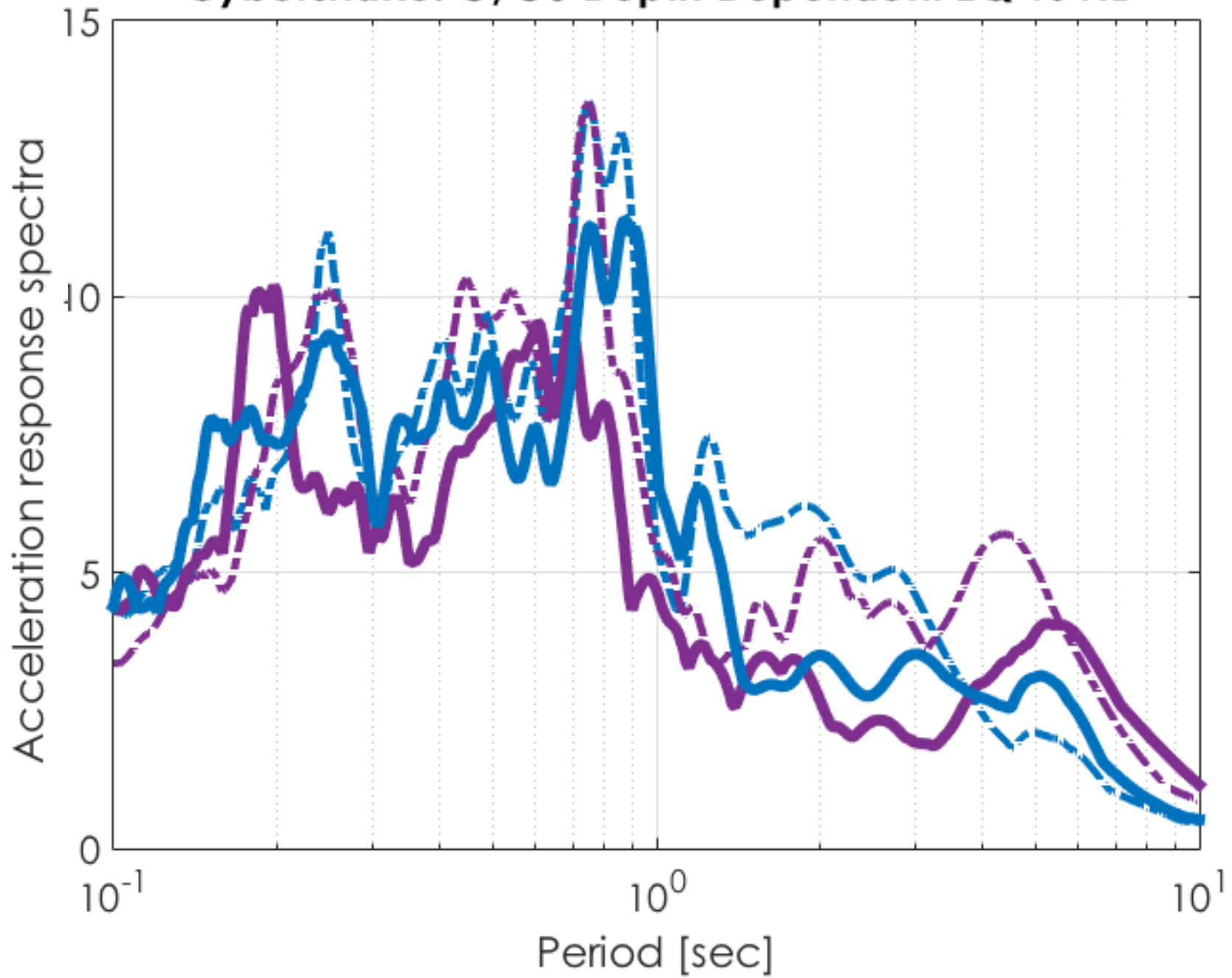Site-Specific Profile: NL Depth dependent G/G0 vs constant (L)
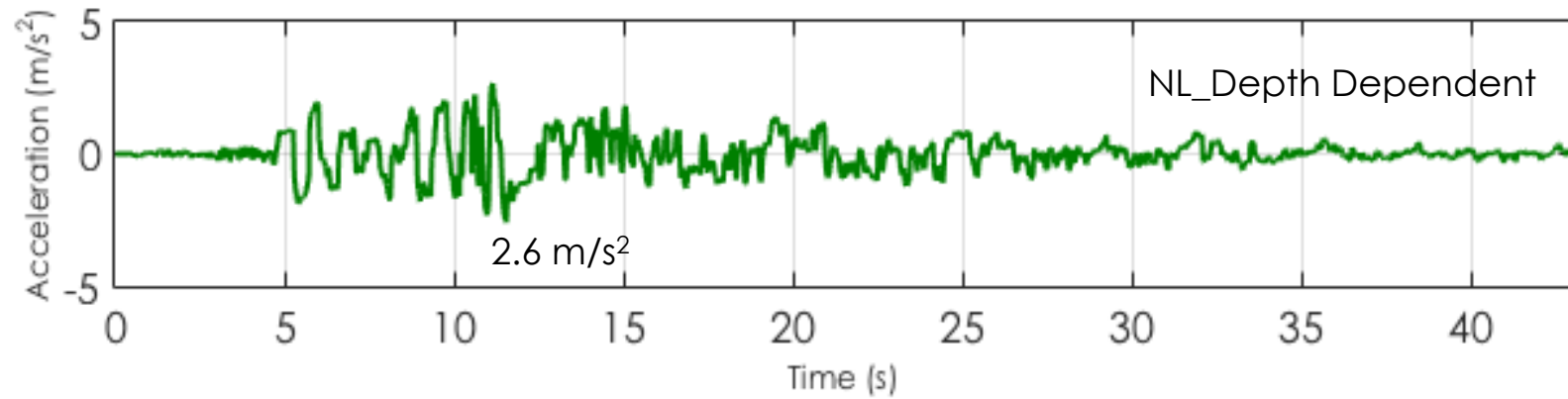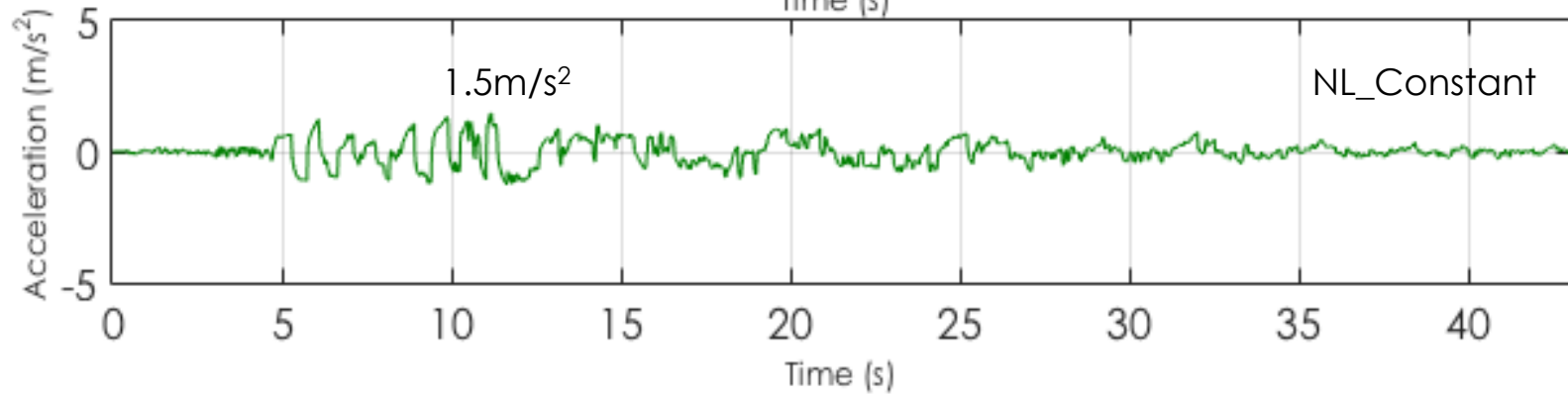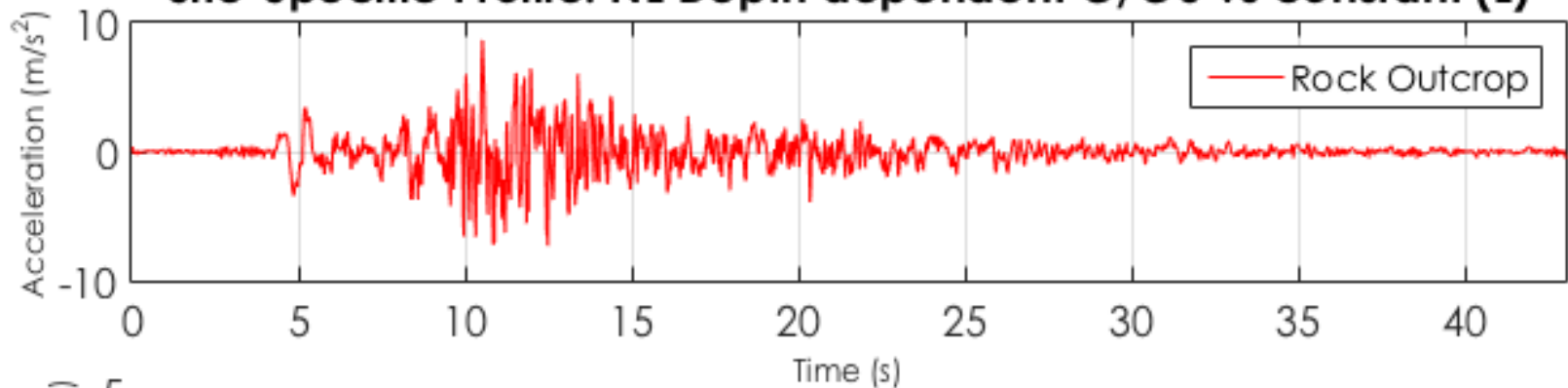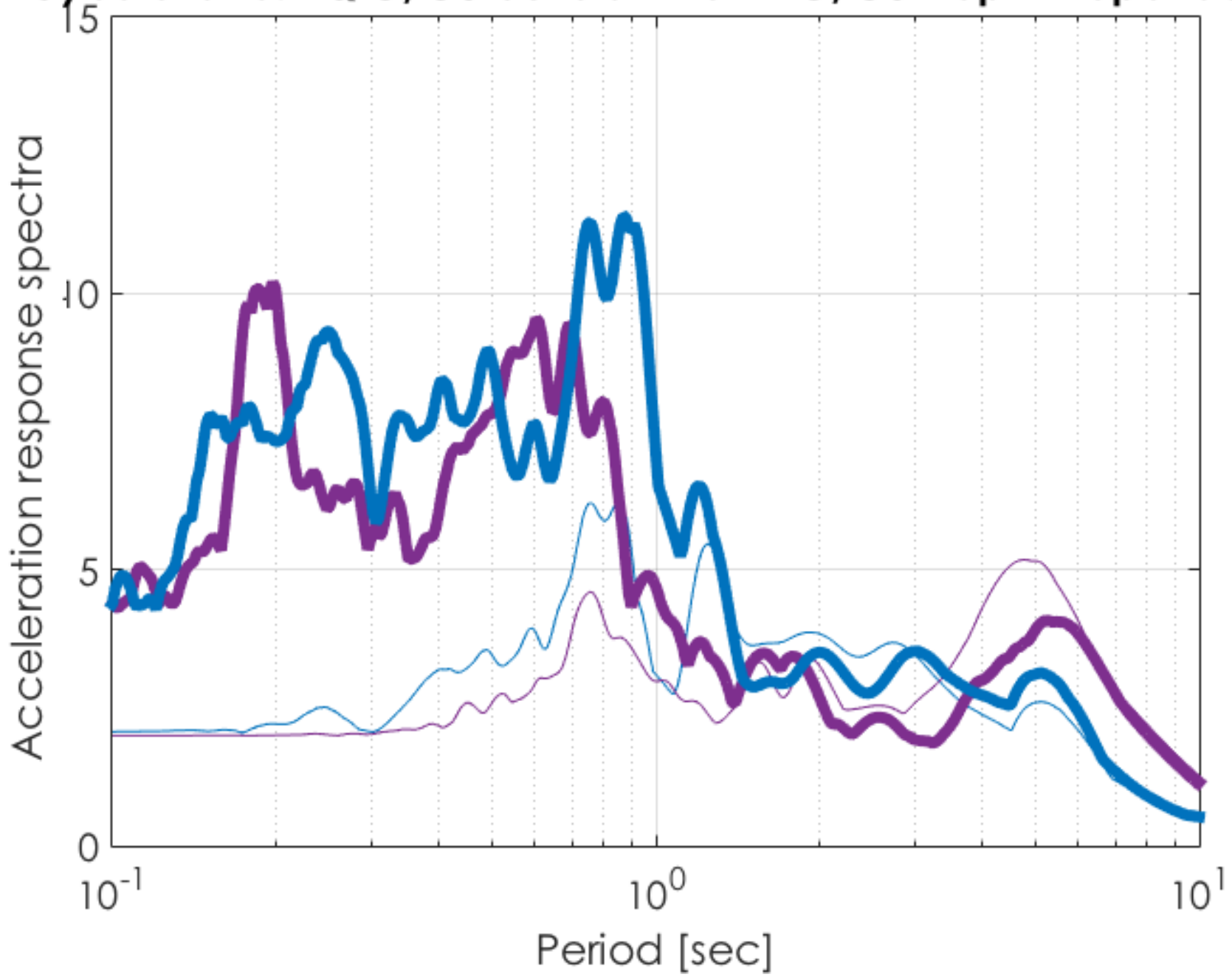
Cybershake: EQ G/G0 constant
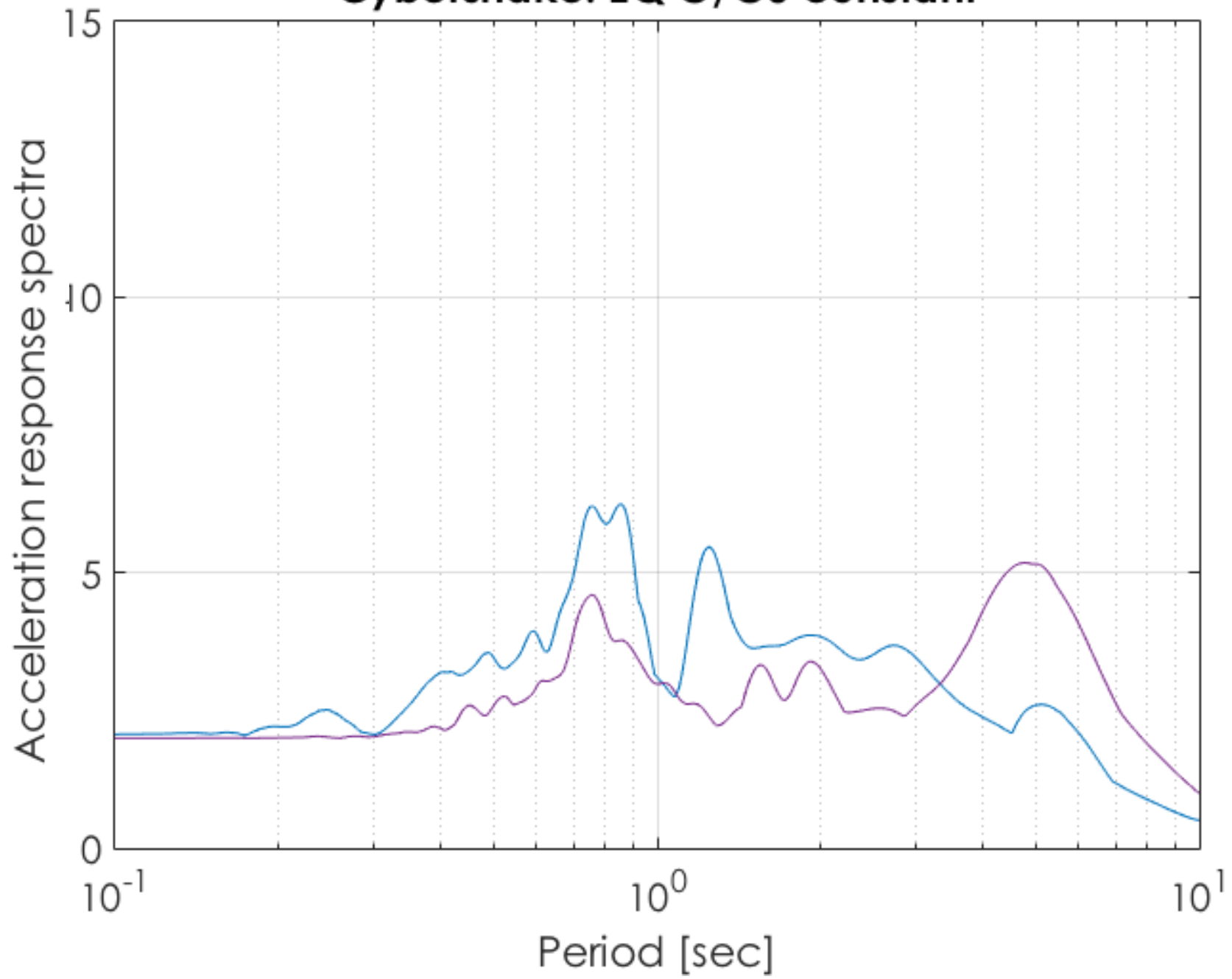
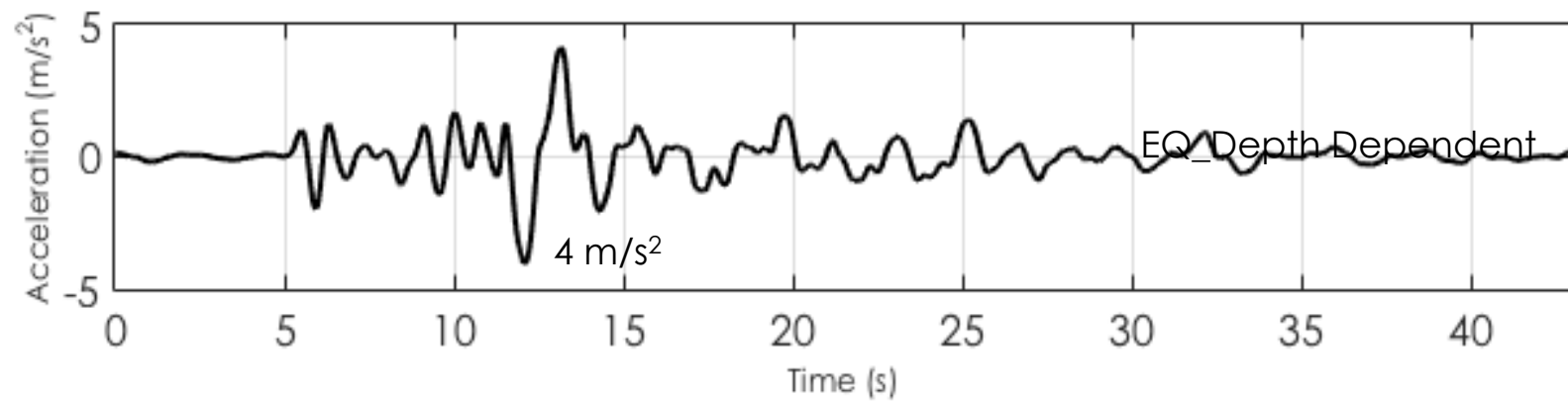Cybershake: G/G0 Constant EQ vs NL
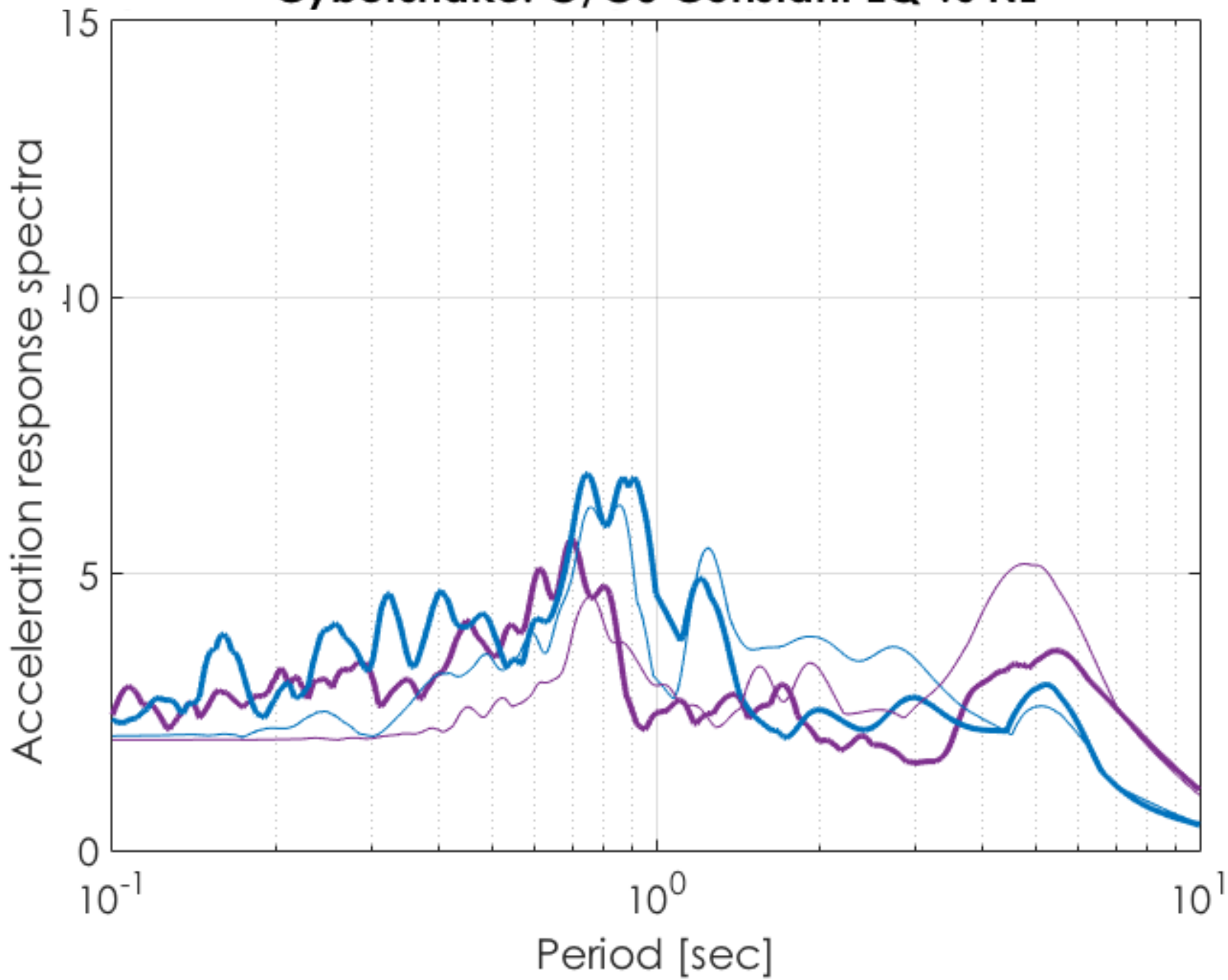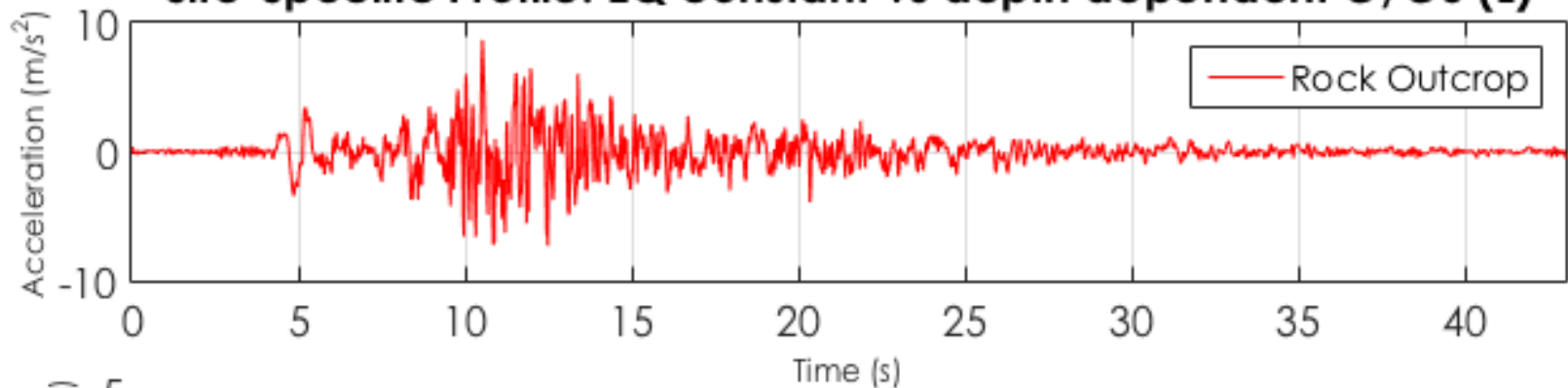
Cybershake: G/G0 Depth Dependent EQ vs NL
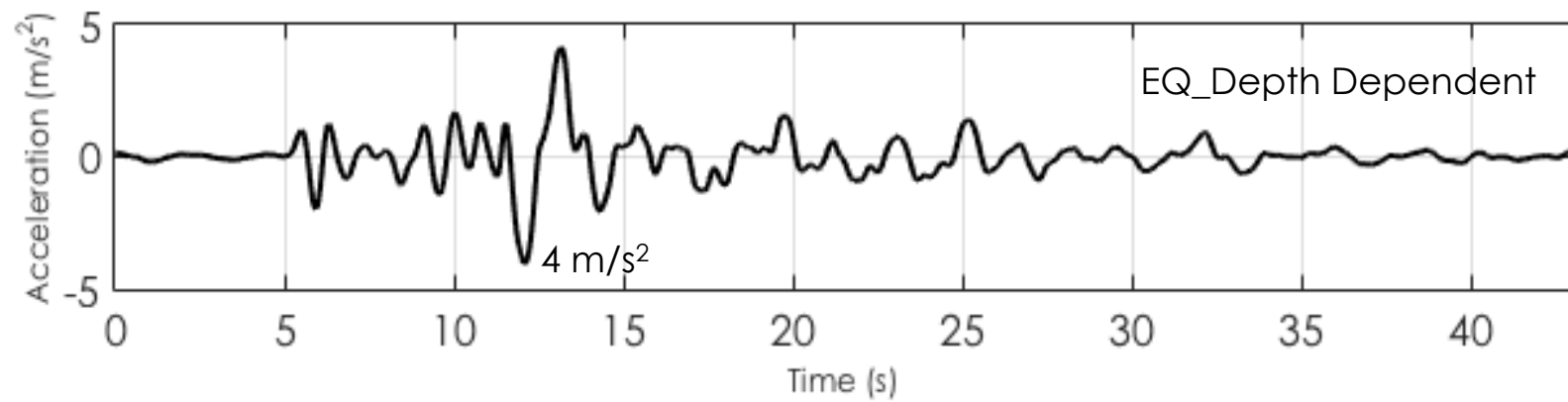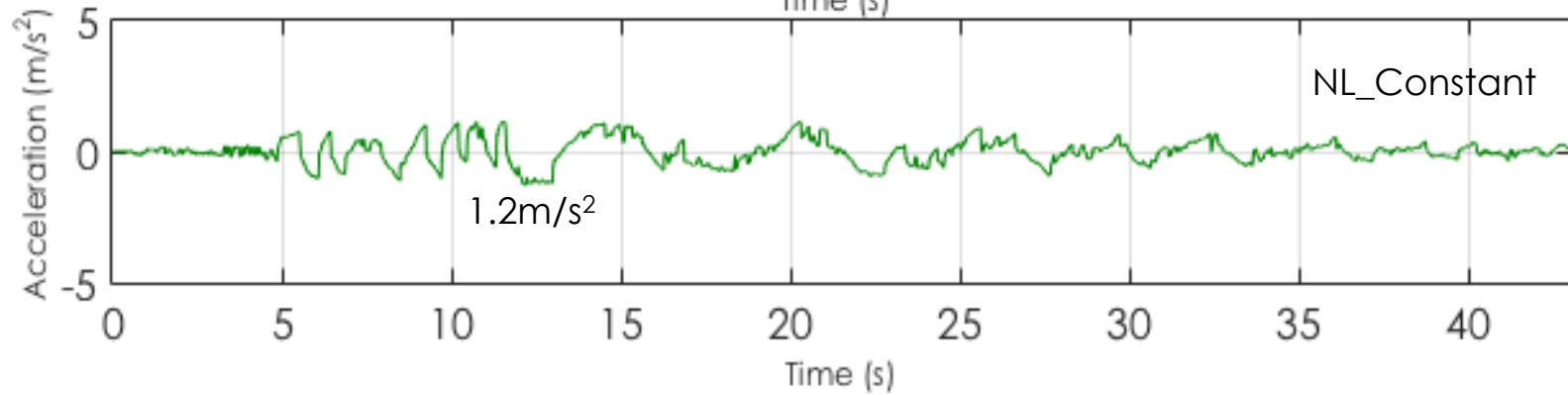
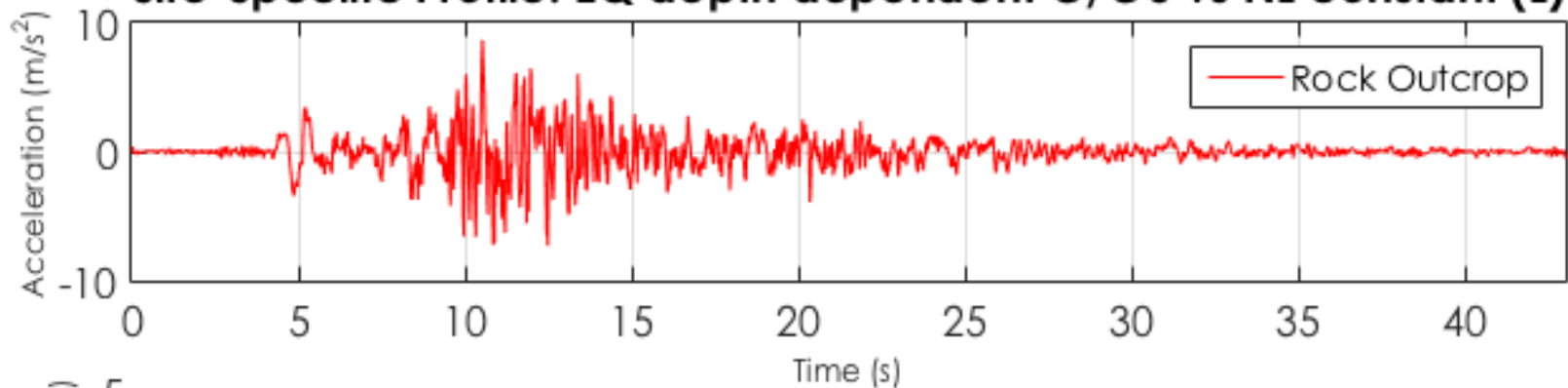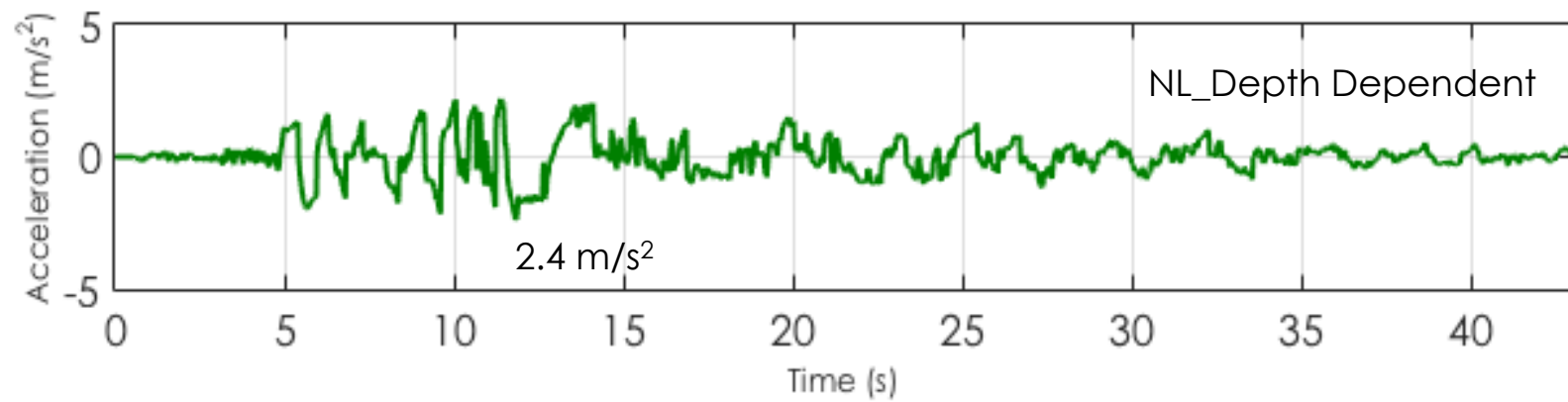Cybershake: EQ G/G0 constant vs NL G/G0 Depth Dependent
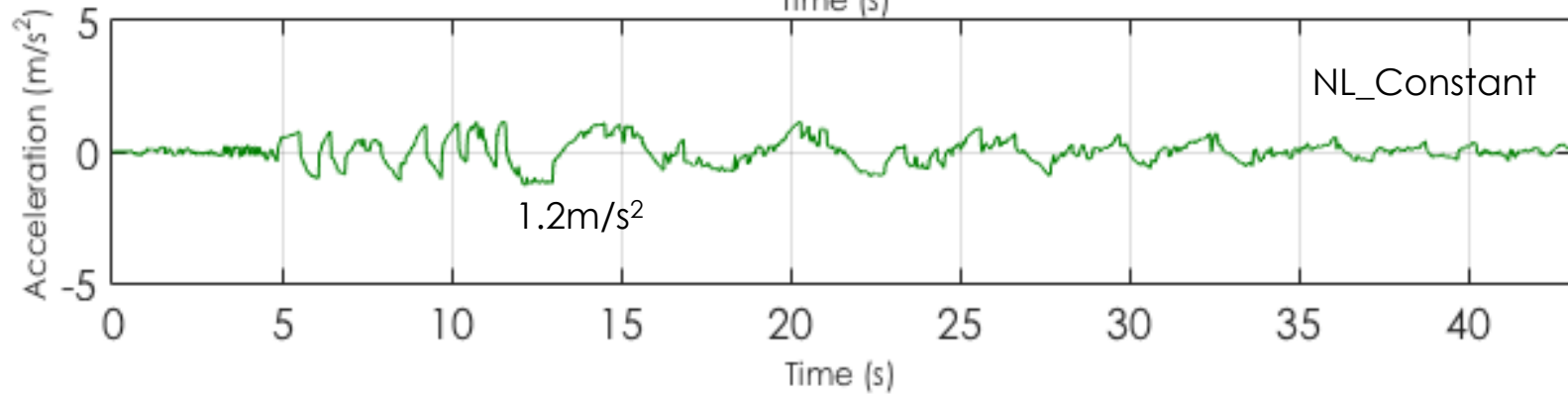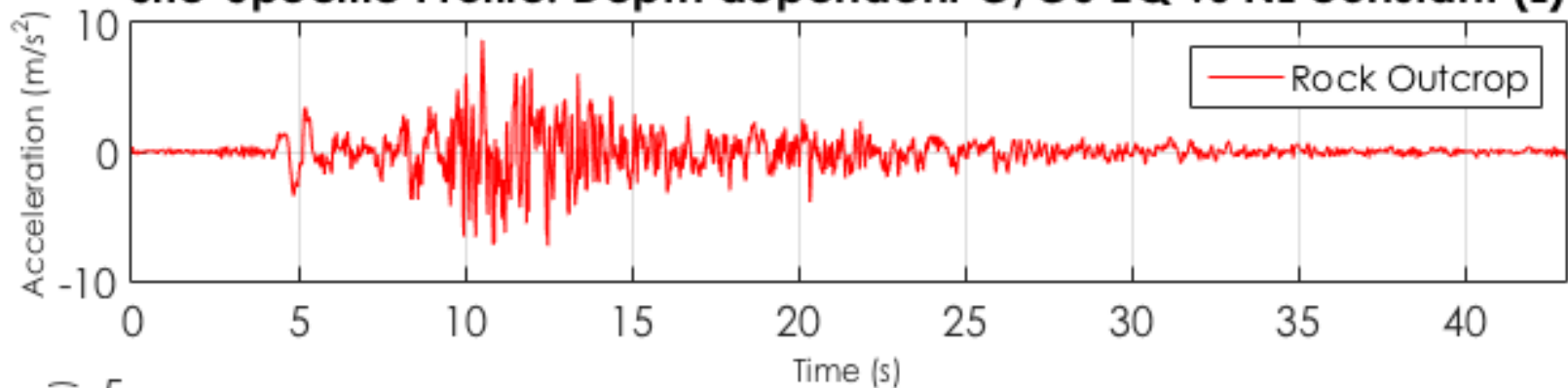
Site-Specific Profile

Site-Specific Profile: EQ constant vs depth dependent G/G0 (L)
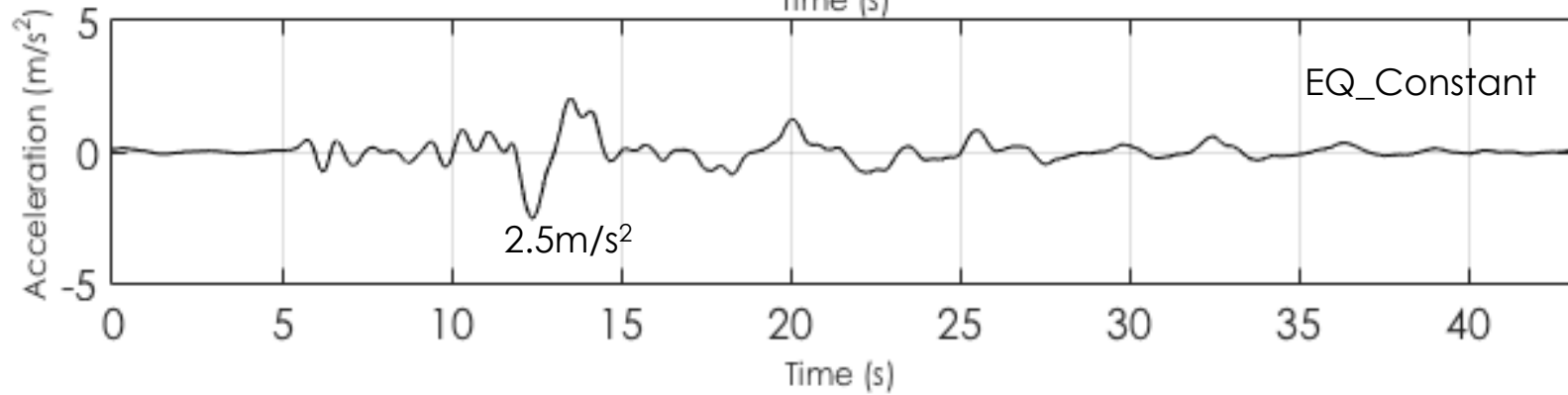
Site-Specific Profile: EQ depth dependent G/G0 vs NL constant (L)
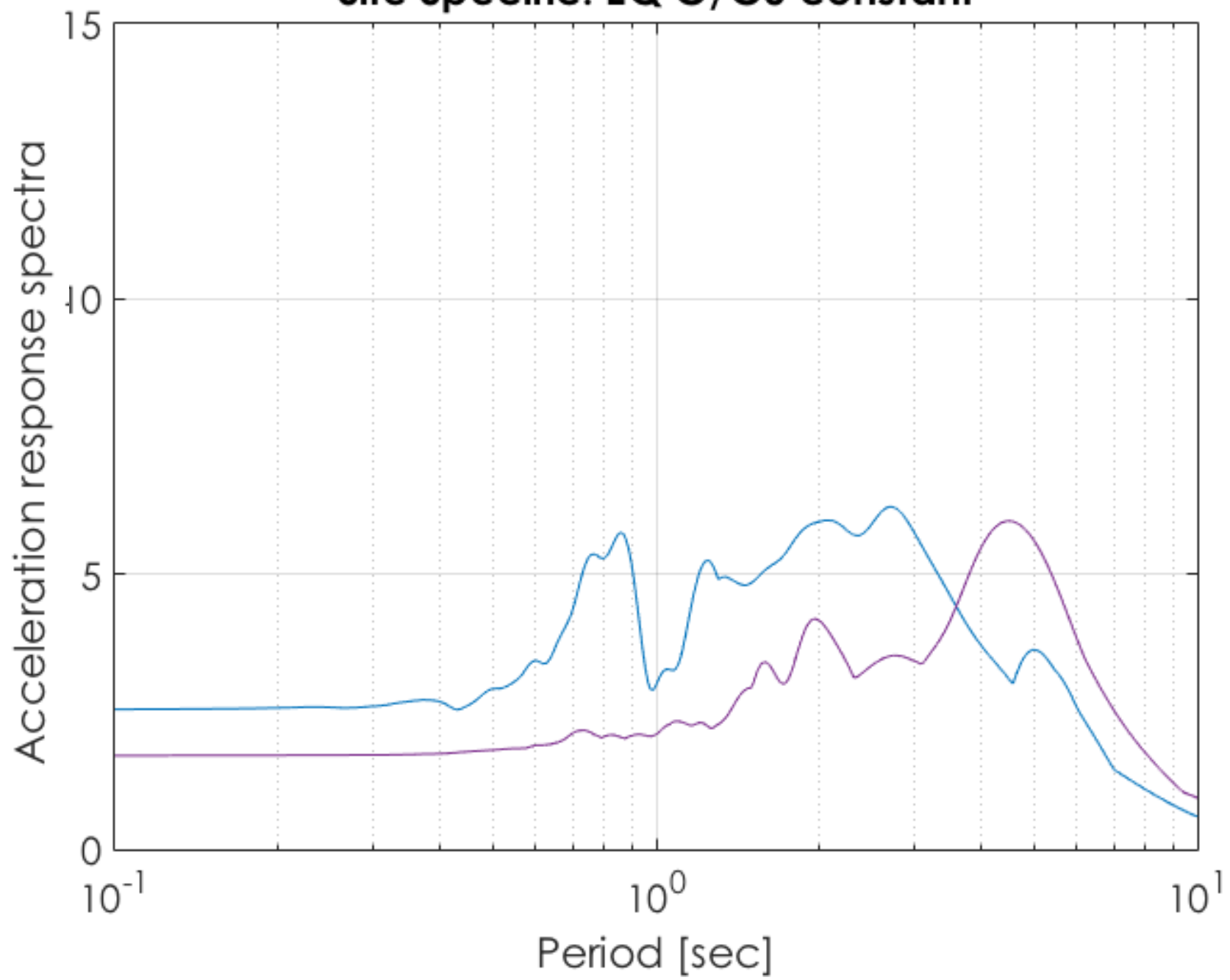
Site-Specific Profile: Depth dependent G/G0 EQ vs NL constant (L)
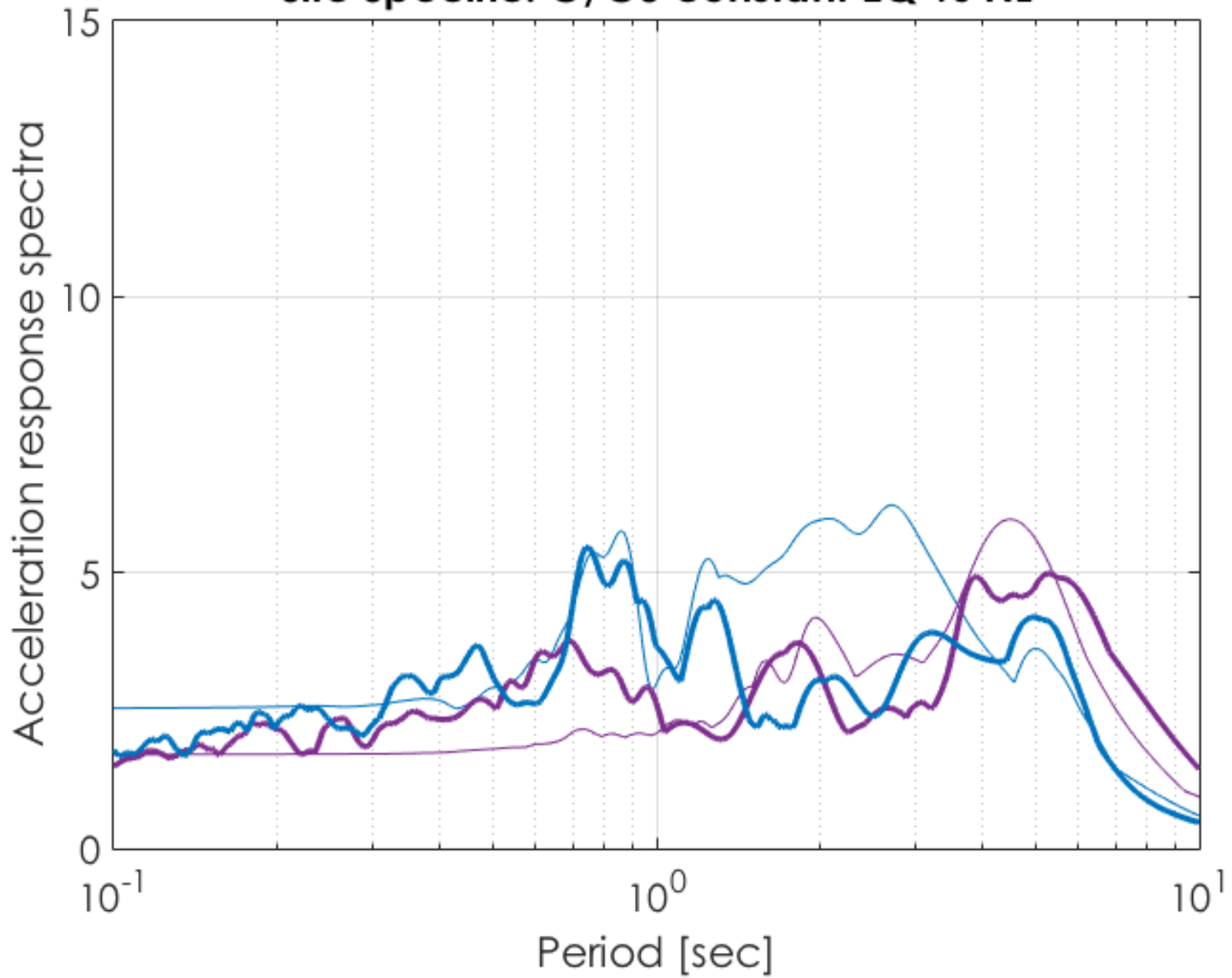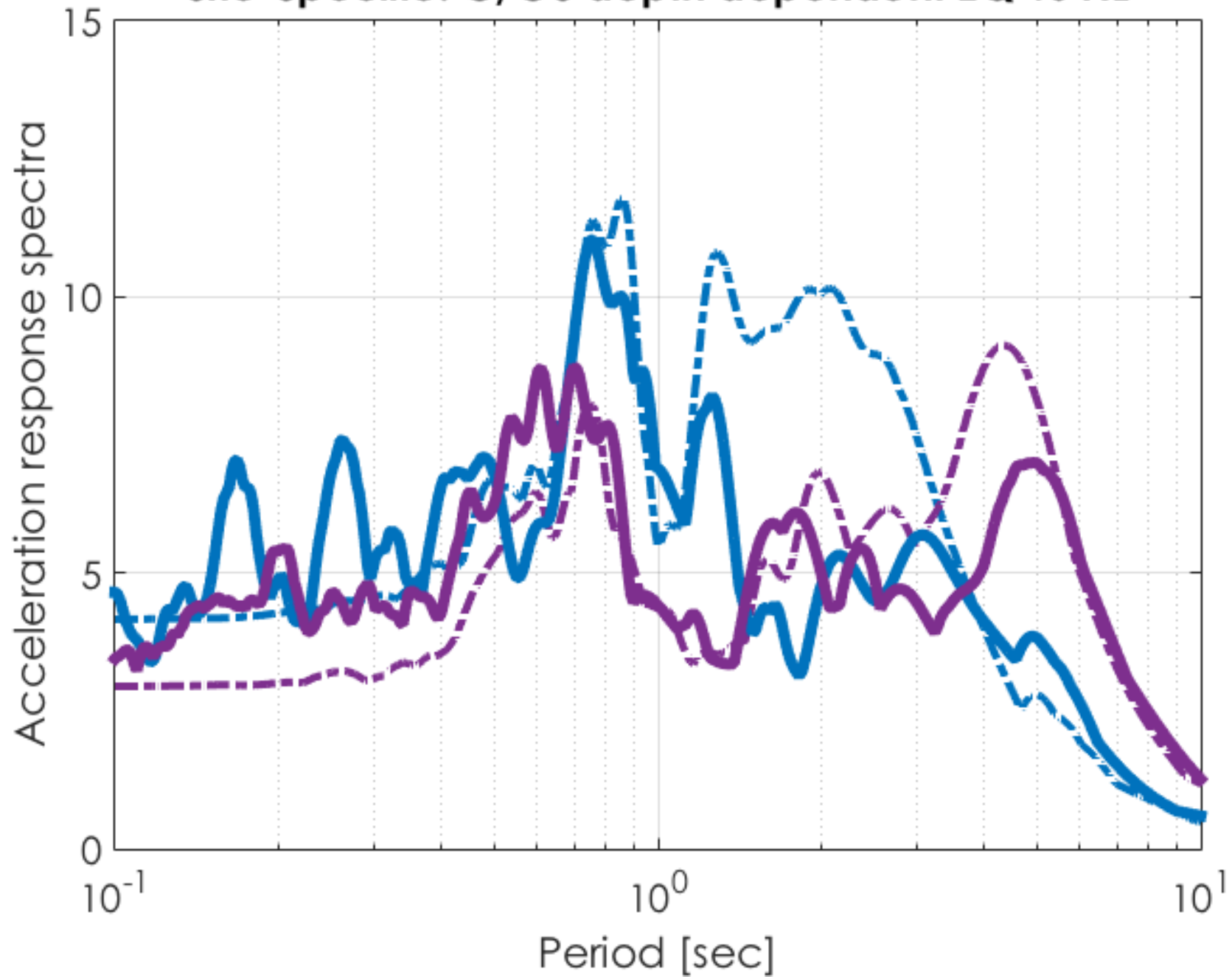
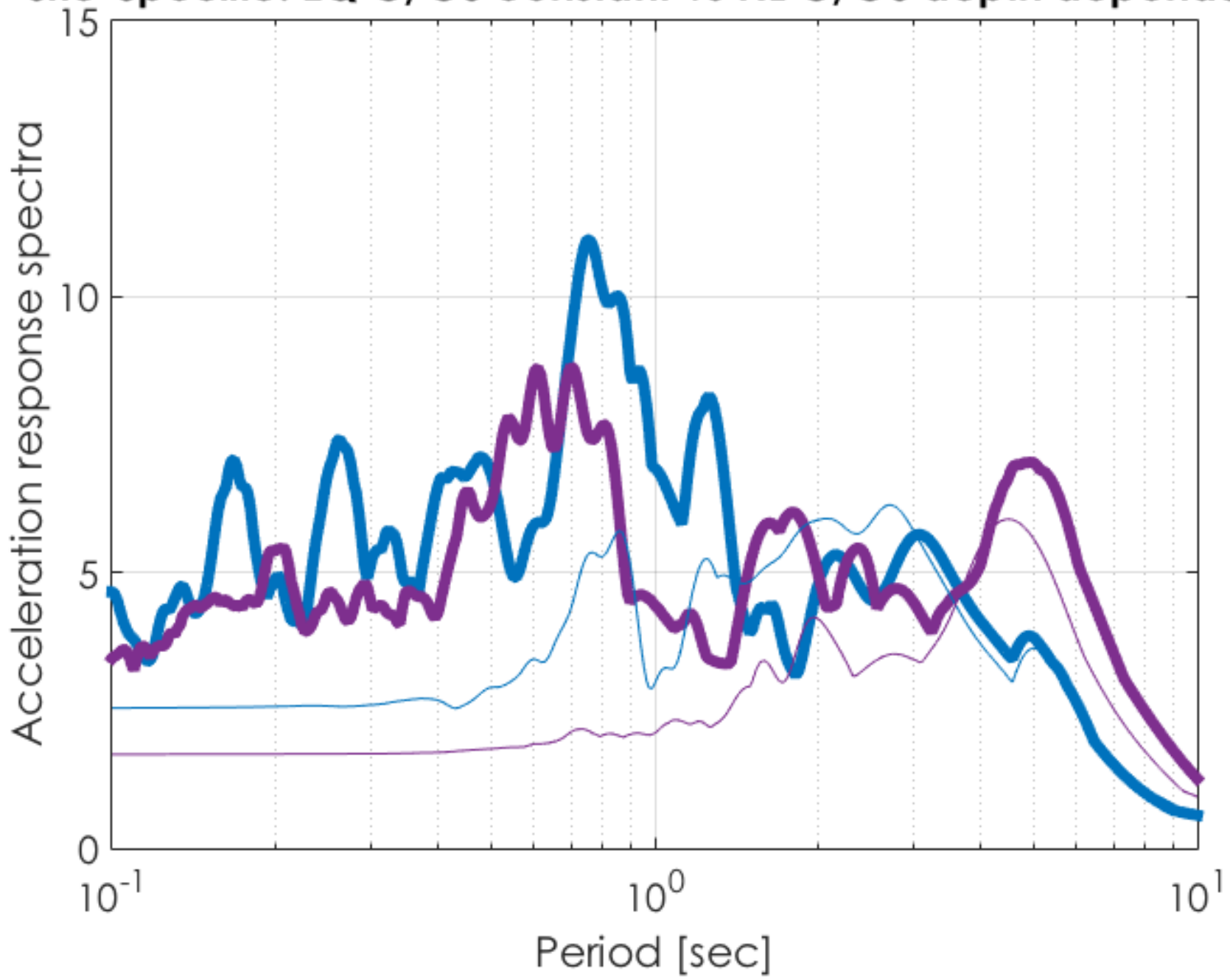# Response Spectra: Scale Factor 1.0

Site Specific: EQ G/G0 constant

Acceleration response spectra vs Period [sec]

Site Specific: G/G0 constant EQ vs NL

Acceleration response spectra vs Period [sec]

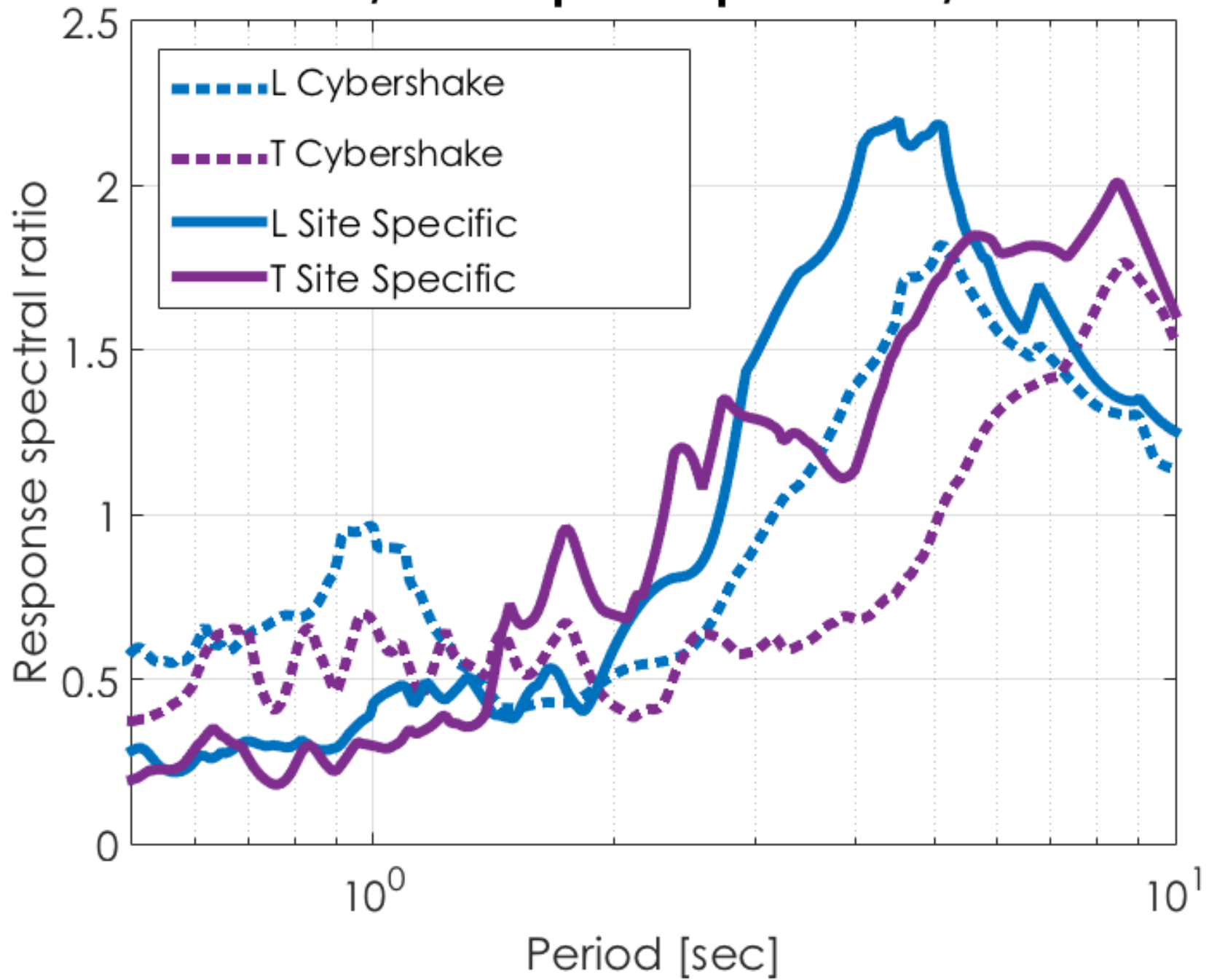Site-Specific: G/G0 depth dependent EQ vs NL

Site-Specific: EQ G/G0 constant vs NL G/G0 depth dependent

Response Spectral Ratios

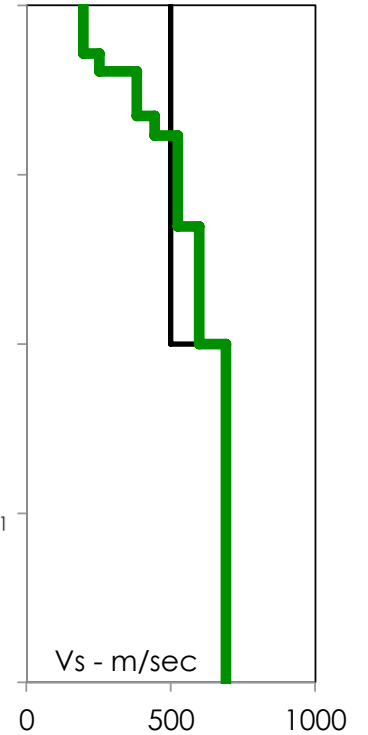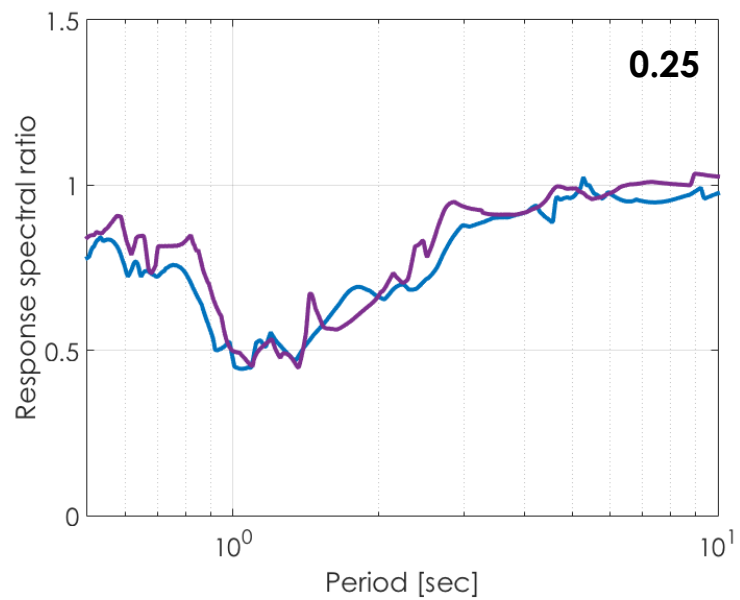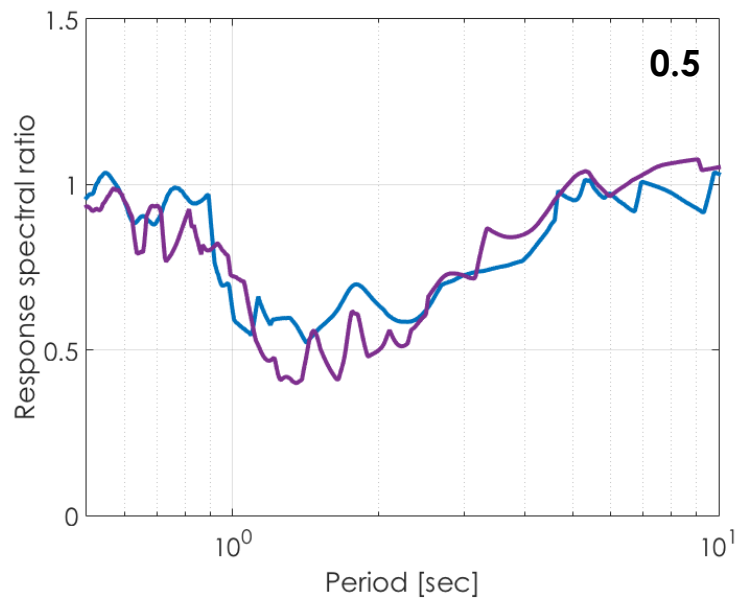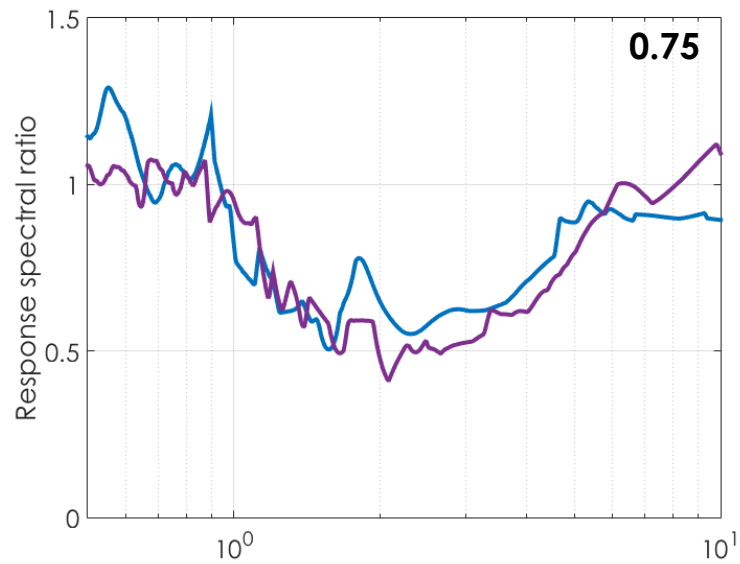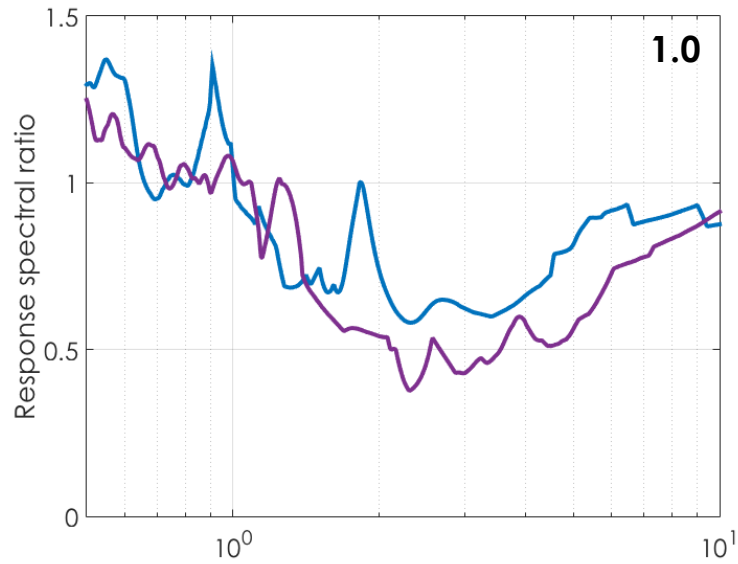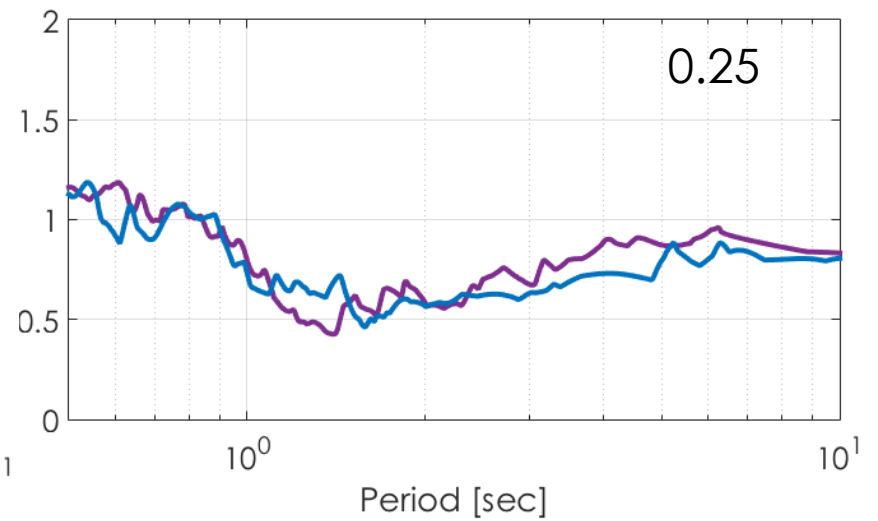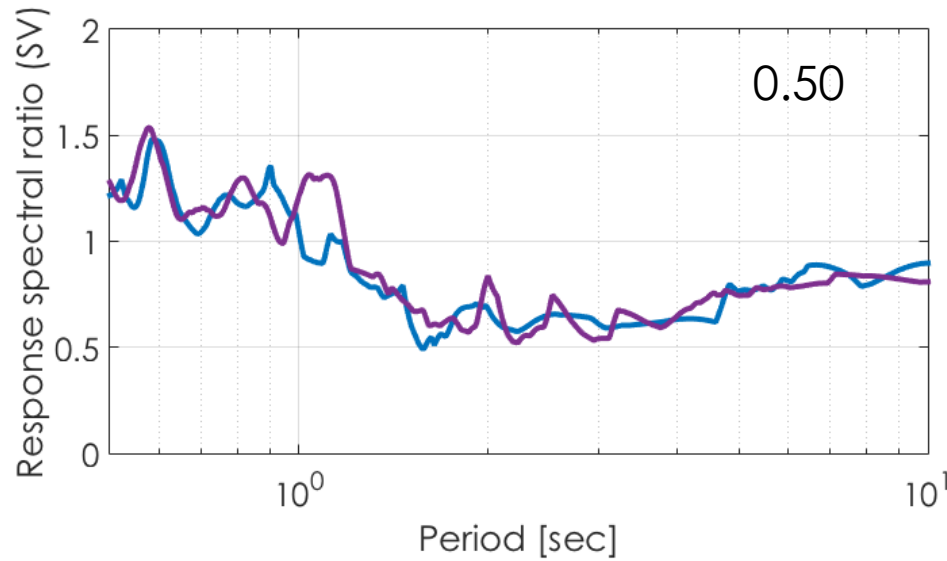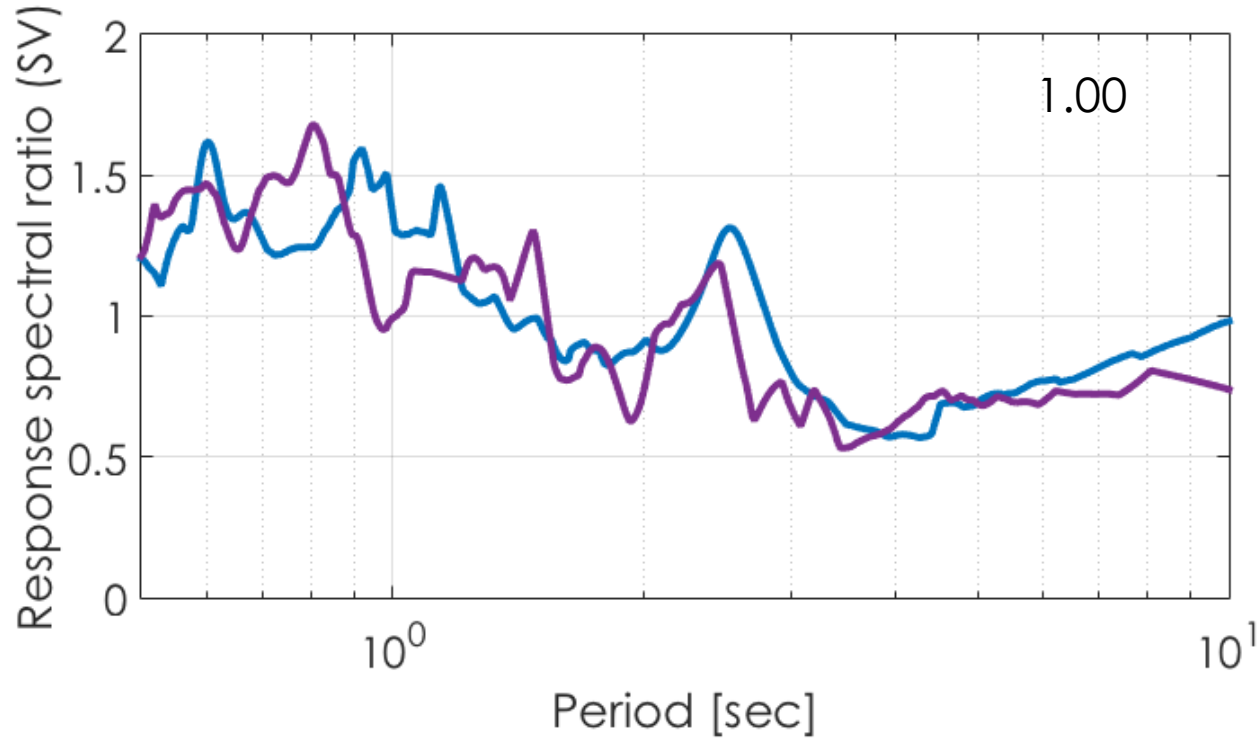**NL G/G0 Depth Dependent / LIN**
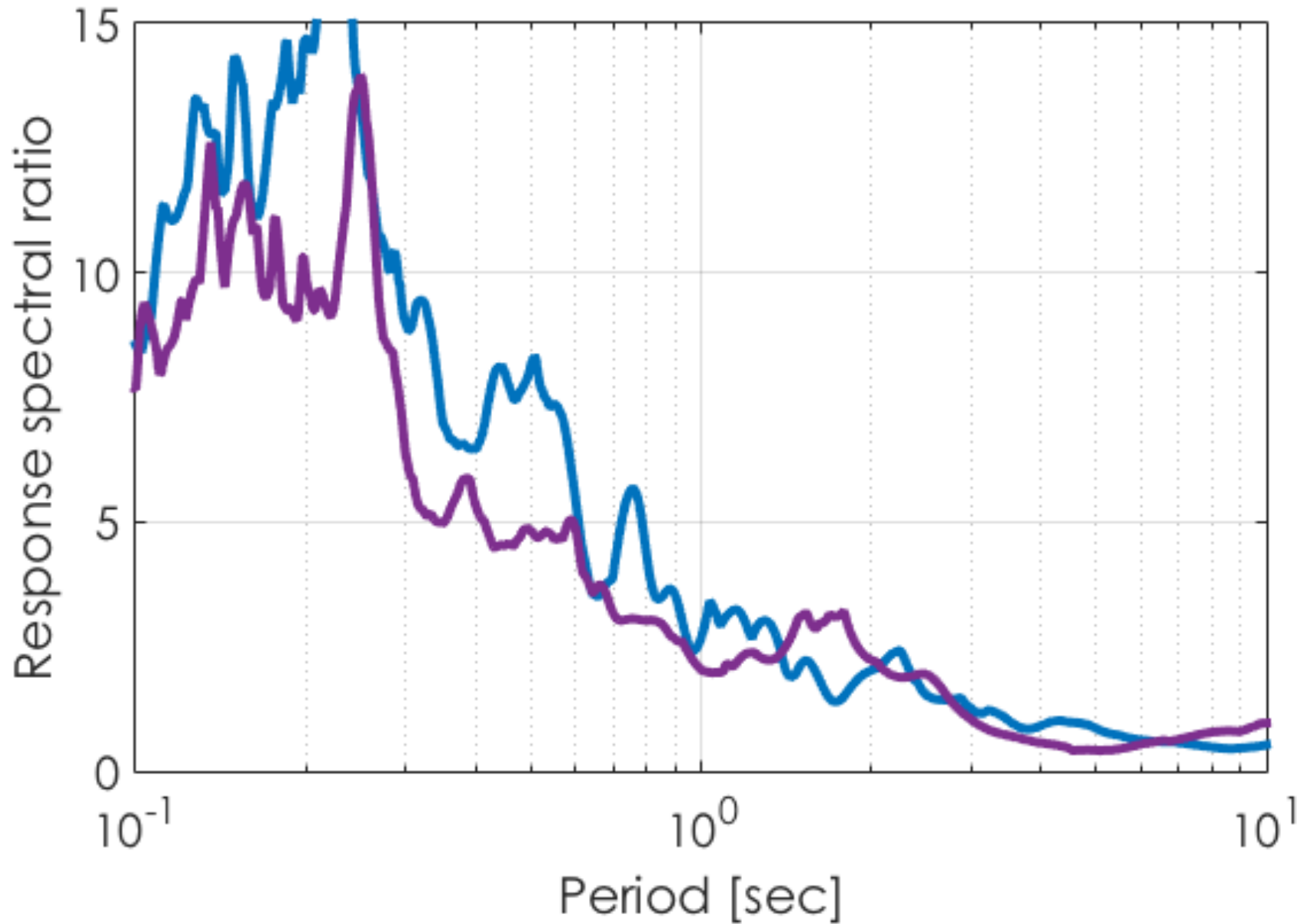
Cybershake / Site-Specific EQL spectral ratio
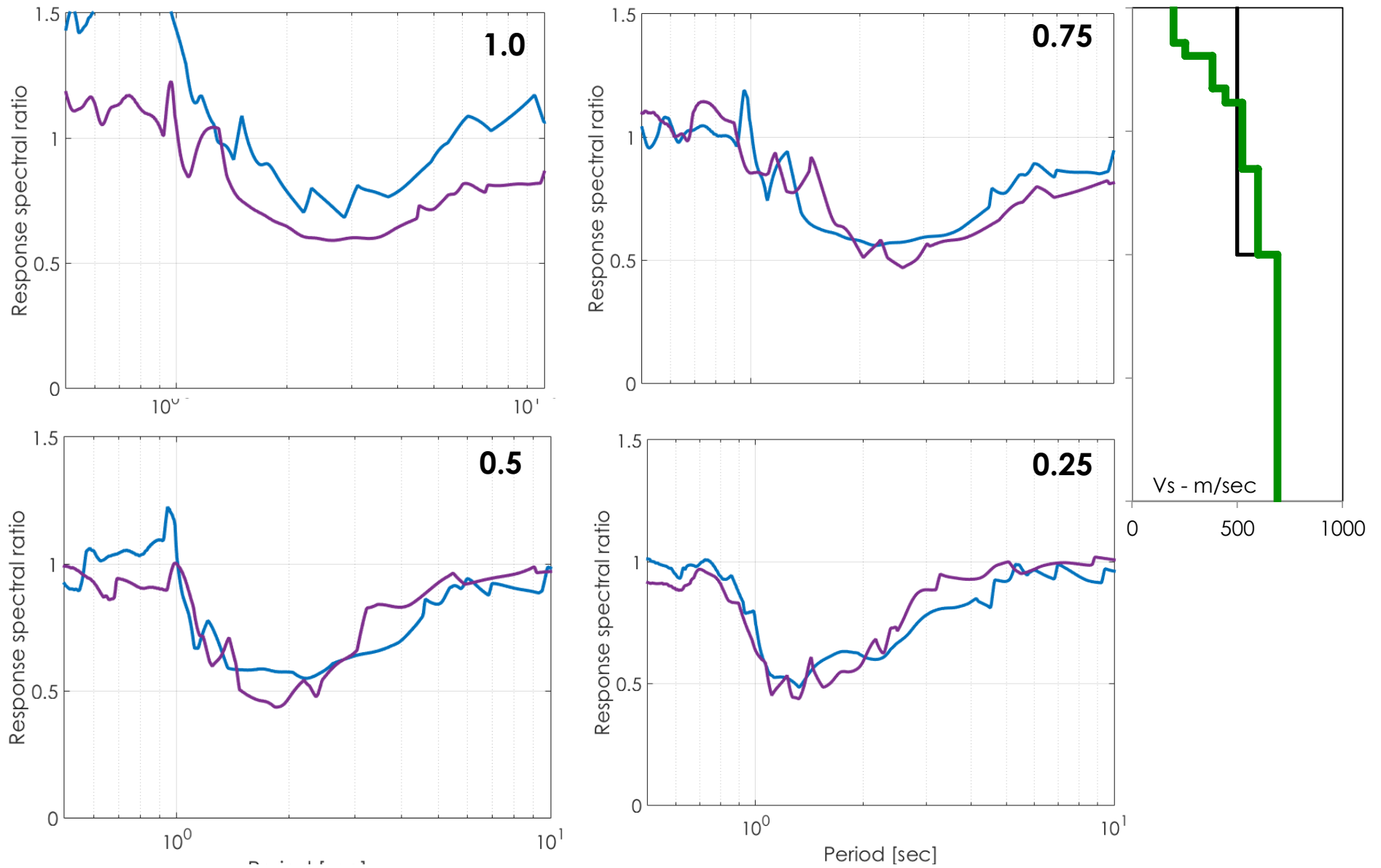
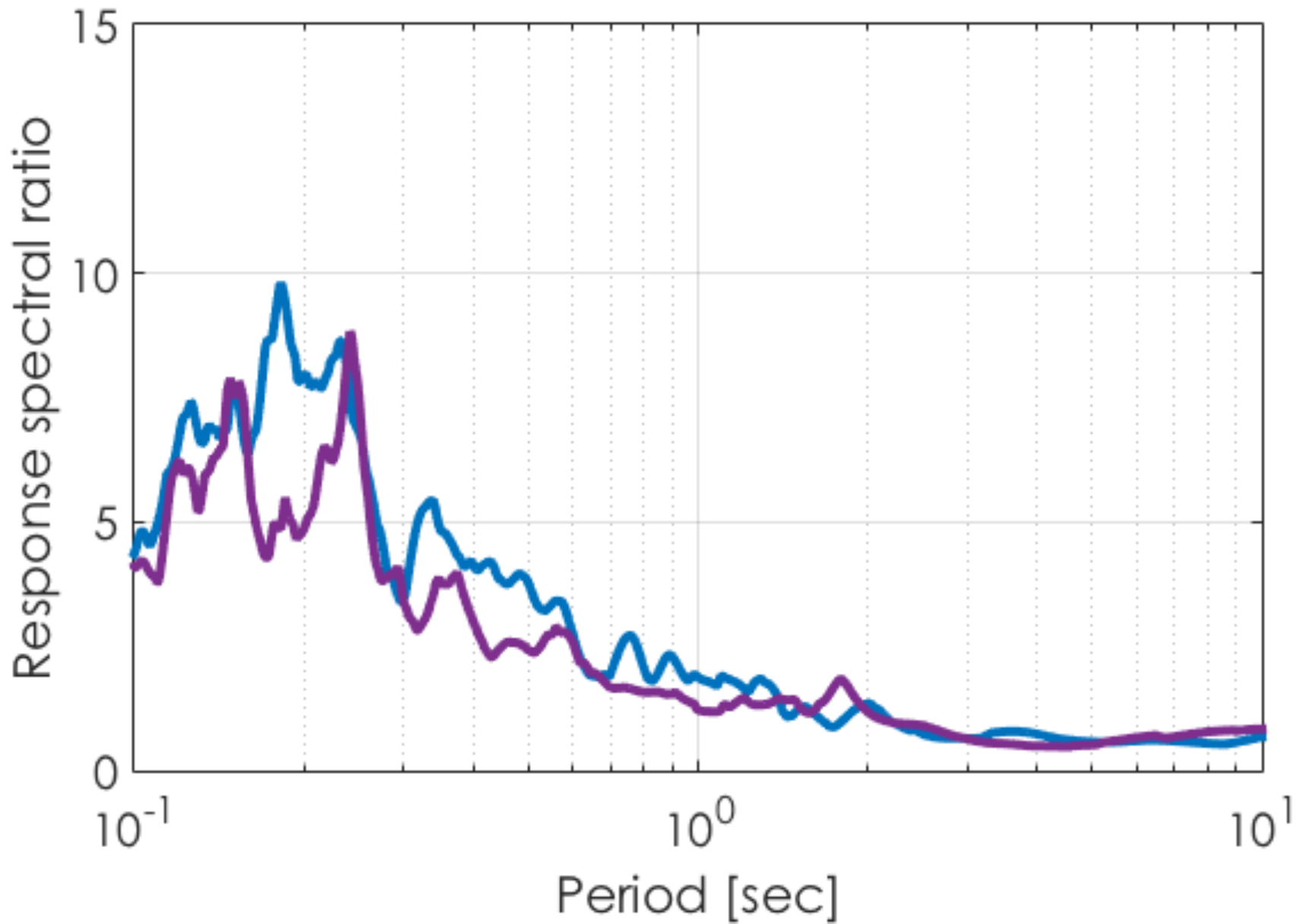# Cybershake / Site-Specific NL spectral ratio

Cybershake / Site-Specific NL spectral ratio (V)

Cybershake LN / Site-Specific NL (1.0)

Cybershake LN / Site-Specific NL (0.5)

Cybershake LN / Site-Specific NL (0.25)