IT7 (SSI) Progress Report
Seismic Pressures on Retaining Walls

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PUC Meeting

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San Francisco, CA

August 2017 PUC Meeting

PUC Agreed with IT7 recommendation to:

Strike from Resource Paper 12 the section on seismic earth pressure

Prepare a new resource paper on the topic of seismic earth pressures.

Nov 2017 PUC Meeting

Proposed approach outlined in brief:

External elements attached to wall – requires SSI analysis, existing procedures sufficient

Free-standing walls: kinematic approach, general framework described (depends on frequency content of ground motion and wall height)

This Meeting

Analysis procedure for free-standing walls

Effect of wall inertia (free-standing walls)

Feedback request

Path forward

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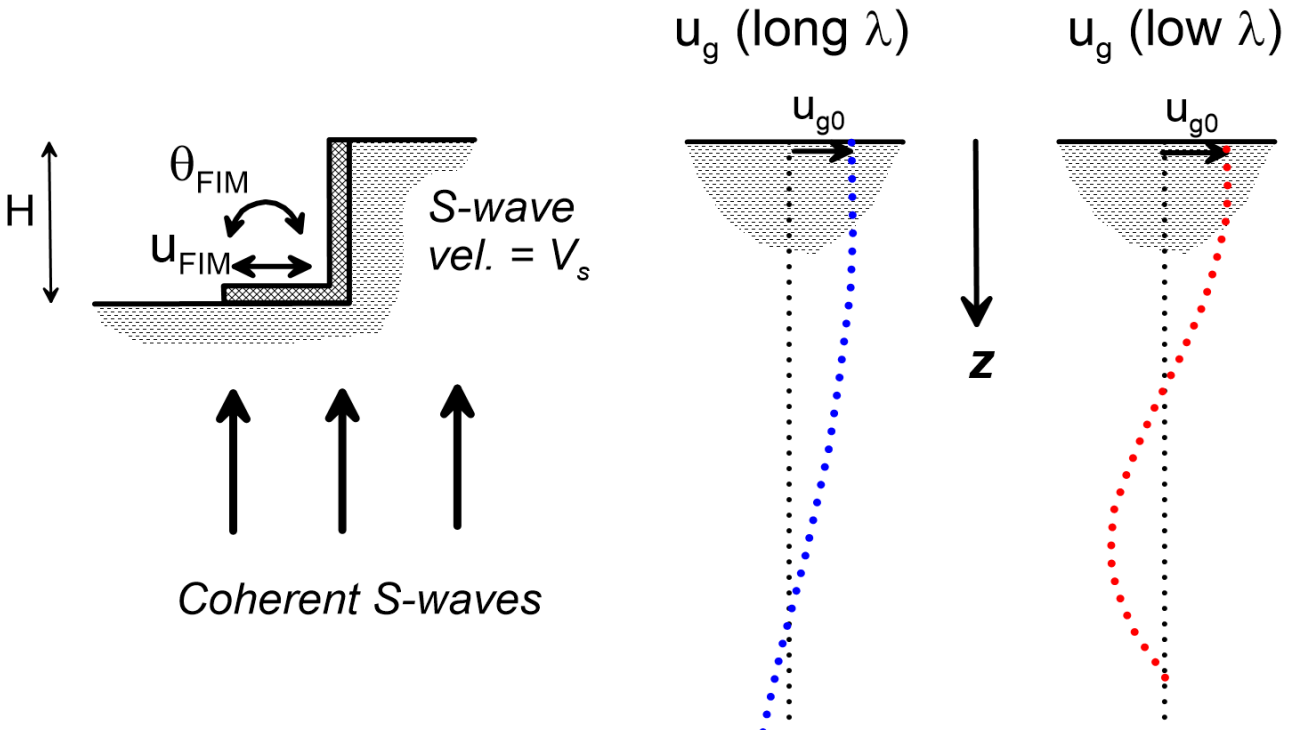
Basis

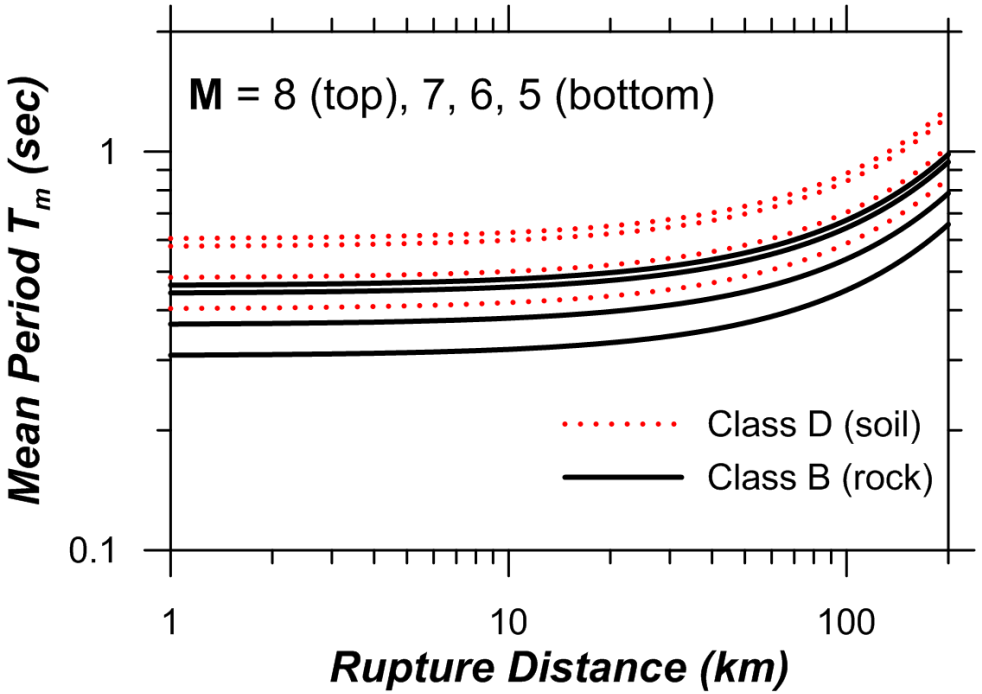


Seismic earth pressures: **Small** **Large**

$$\lambda = V_{s,av} T_m$$

Reasonable range of $V_{S,av}$: 100 – 300 m/s

Reasonable range of T_m: 0.3-0.7 sec (WUS)

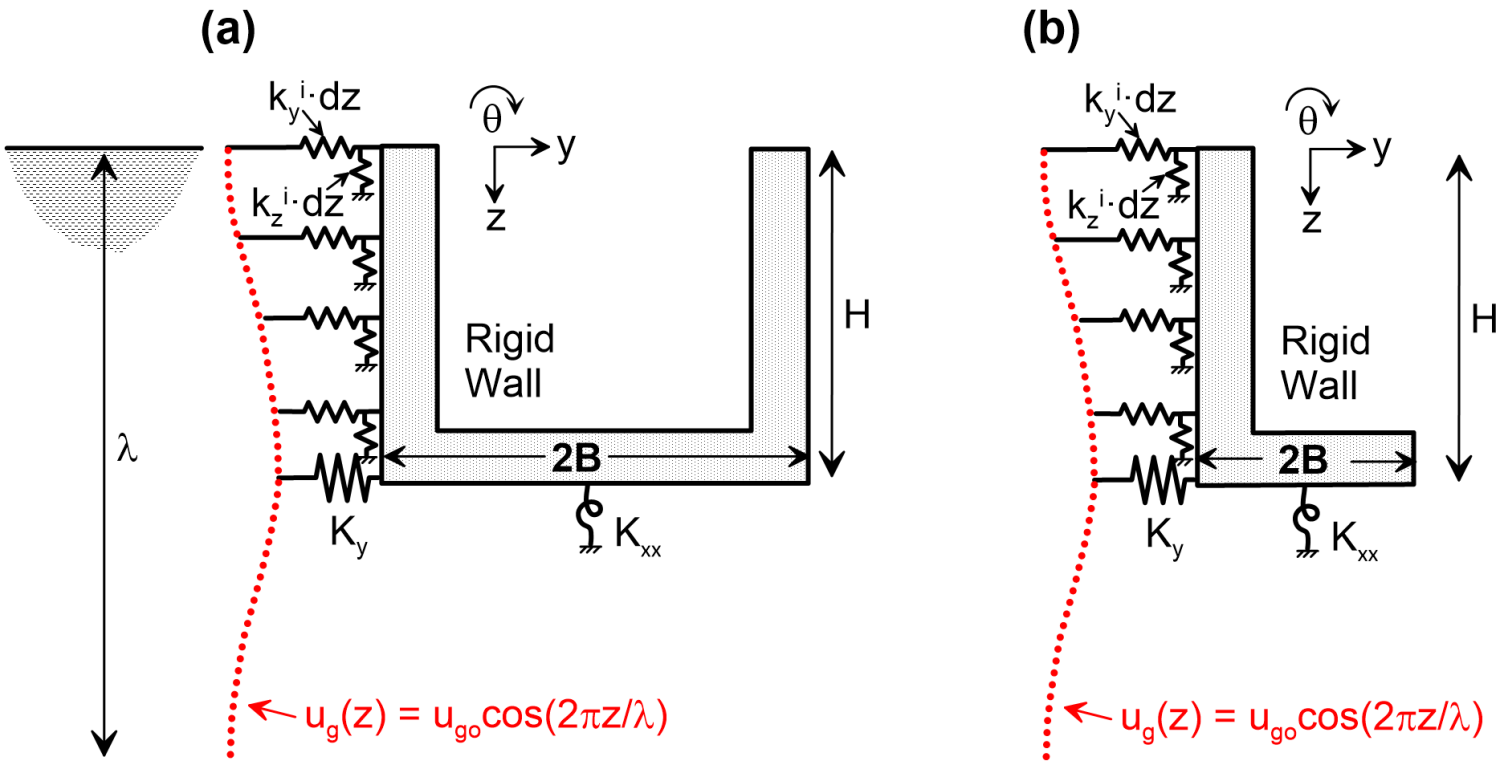


Rathje et al. 2004 GMM

Approximate Range of Wavelengths, λ

$V_{S,av}$ \ T_m	0.3 sec	0.5 sec	0.7 sec
100 m/s	30 m	50 m	70 m
200 m/s	60 m	100 m	140 m
300 m/s	90 m	150 m	210 m

System Considered



Foundation dimensions usually taken as half-widths, *B*, in impedance function solutions

Logic Behind Procedure

Ground motion represented by a single frequency and suitable ground motion amplitude (related to PGV)

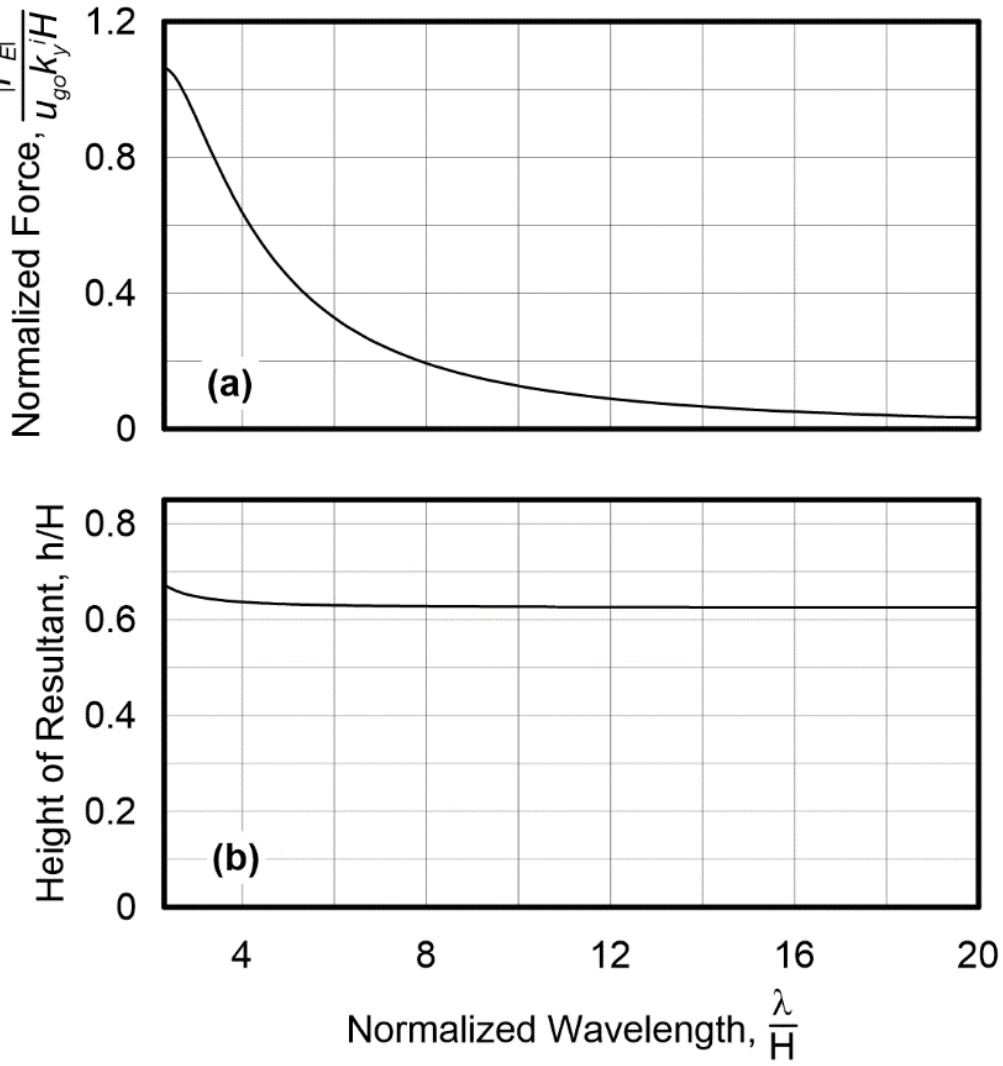
Backfill V_S profile & analysis of how reduced by modulus reduction effects

Evaluate wall-soil interface stiffness, k_y^i

Normalized seismic wall force evaluated as function of $\lambda/H = V_{S,av}T_m/H$. Optional factors can be considered to reduce normalized force

De-normalization using amplitude, k_y^i, H

- Fixed base
- Rigid wall
- Uniform backfill

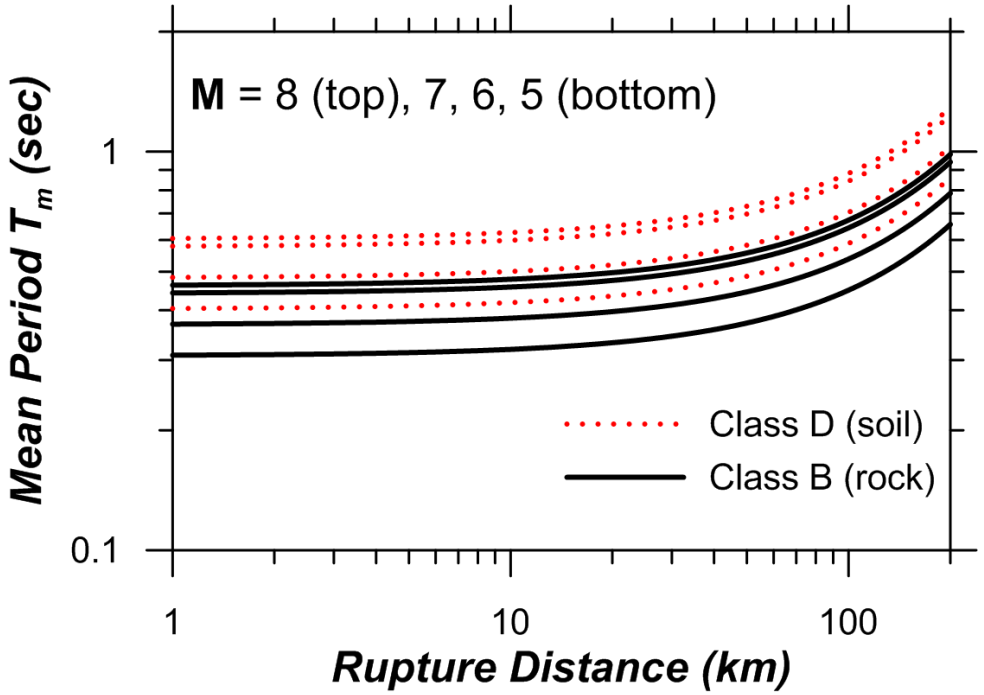


$$\frac{|P_E|}{k_y^i u_{g0} H} = cos(kH) - \frac{\sin(kH)}{kH}$$

Detailed Procedure

1. Seismic hazard analysis to obtain PGV

2. Identify **M** and R related to PGV (de-aggregation, or deterministic values). Estimate T_m. Compute corresponding angular frequency $\omega_m = 2\pi/T_m$.



Rathje et al. 2004 GMM

Detailed Procedure

3. Measure or estimate V_S profile. Adjust for strain effects. Average of reduced profile is $V_{S,av,r}$

4. Potentially neglect seismic earth pressures if $\lambda/H = V_{S,av,r}T_m/H$ exceeds some value (perhaps 15)

e.g., 200 m/s, Tm = 0.5 sec, H = 5m

$$\lambda/H = 20$$

5. Estimate ground motion amplitude, $u_{g0} = f_u\, PGV/\omega_m$, where factor f_u depends on λ/H (generally between 0.65 and 0.95).

Detailed Procedure

6. Compute normalized force amplitude, $|P_E|/\left(k_y^i u_{g0} H\right)$. Adjust for flexible base, inhomogeneous backfill, flexible wall, if desired (reduces force)

7. Compute k_y^i, depends on

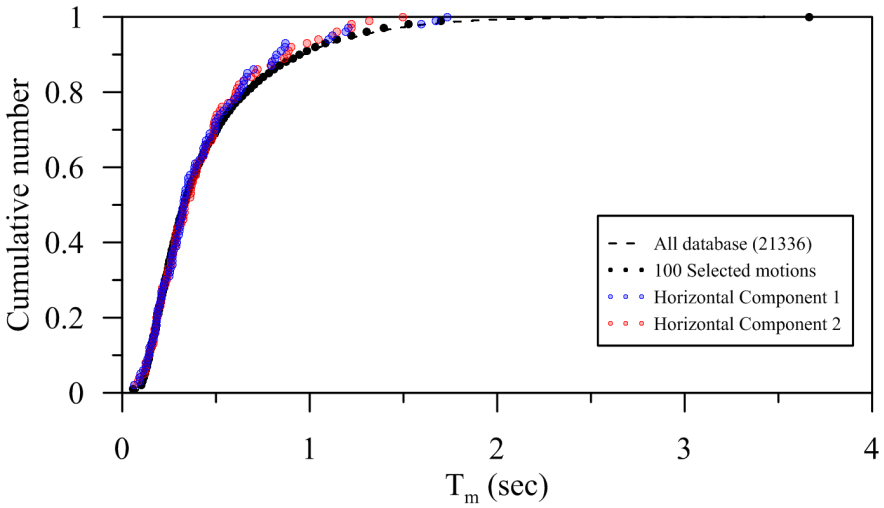
$$k_y^i = \frac{\pi}{\sqrt{(1-\nu)(2-\nu)}} \frac{G}{H} \sqrt{1-\left(\frac{4H}{\lambda}\right)^2}$$

where $G = \rho V_{S,av,r}^2$ and ν = soil Poisson's ratio

8. De-normalize P_E.

Verification

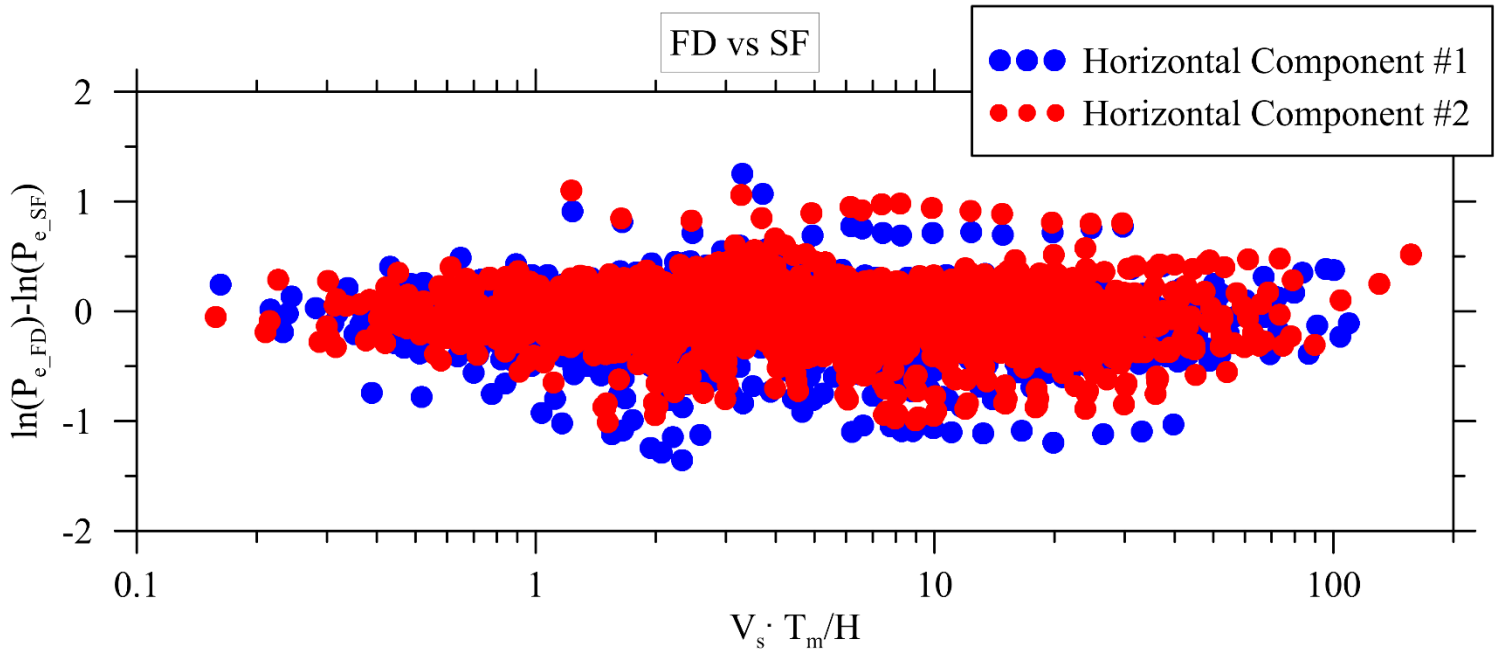
Full Fourier analysis vs use of single frequency ground motions selected to have range of T_m:



Each motion run though wall – full analysis

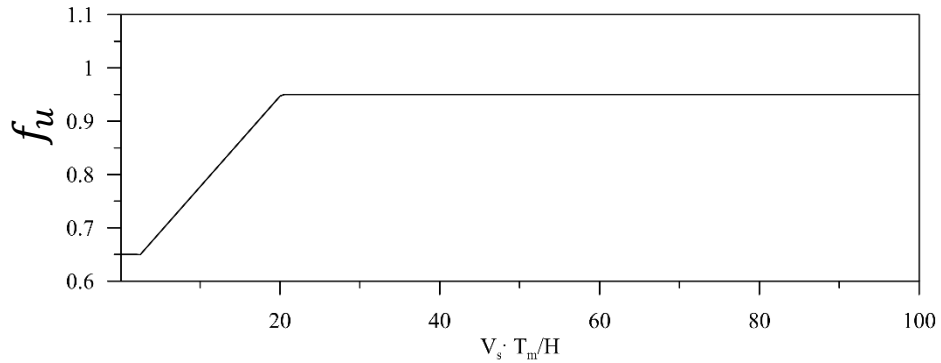
Single frequency method used with motions amplitude and mean period

Difference computed: $ln(P_{E,full}) - ln(P_{E,sf})$



Standard deviation Horizontal Component #1: 0.2808
Standard deviation Horizontal Component #2: 0.2776

Mean error Horizontal Component #1: -0.0556
Mean error Horizontal Component #2: -0.0299



$$f_u = \begin{cases} 0.65 \; for \; \dfrac{V_s T_m}{H} < 2.5 \\ 0.017 * \dfrac{V_s T_m}{H} + 0.607 \;\; for 2.5 \leq \dfrac{V_s T_m}{H} \leq 20 \\ 0.95 \; for \; \dfrac{V_s T_m}{H} > 20 \end{cases}$$

This Meeting

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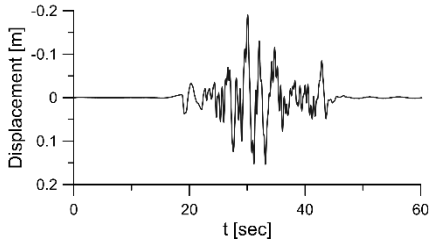
Effect of wall inertia (free-standing walls)

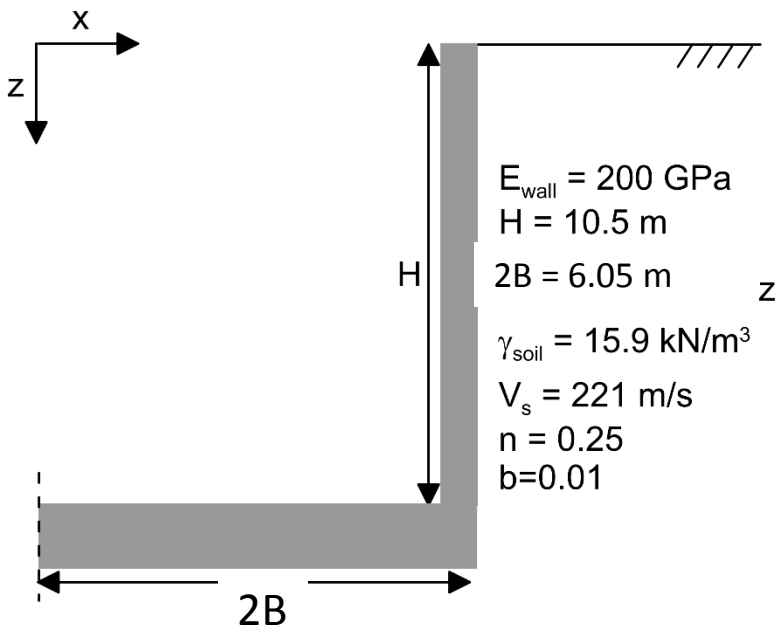
Feedback request

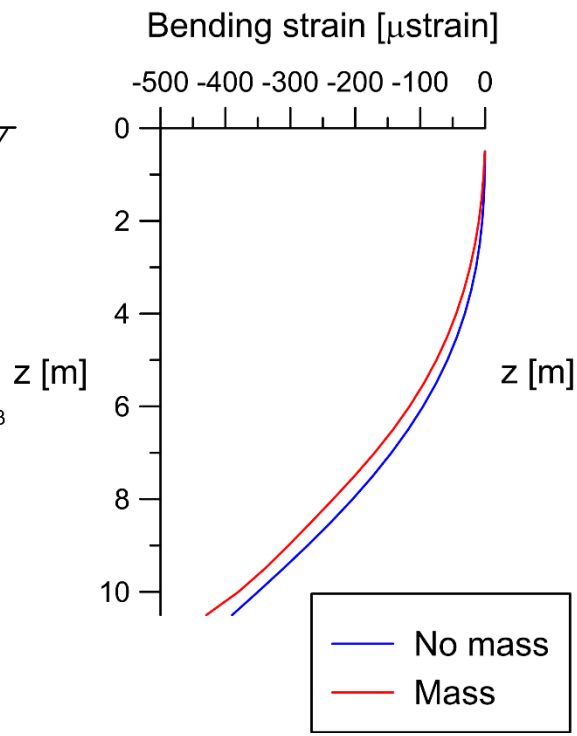
Path forward

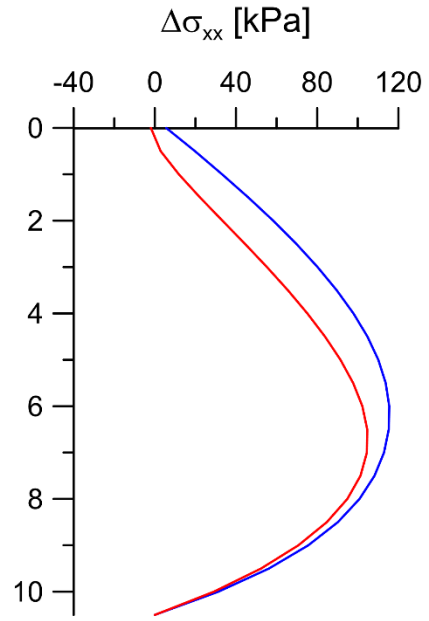
Effect of wall inertia

Ground motion:
Loma Prieta Earthquake 1989
(LGPC Station) – PGA 1.05g









Difference at the peak ≃ 9%

Configuration: flexible wall, rigid base, inhomogeneous soil deposit

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This procedure is a significant departure from current practice

Parameter	MO Approach	SSI Approach*
Wall dimensions	H	H, B
Soil stiffness	--	Vs,av
Soil strength	ϕ, c	--
Ground motion amplitude	PGA	PGV
Ground motion frequency	--	Tm

* Simplest case (fixed base, rigid wall, uniform soil

Feedback requested on whether this appears reasonable from point of view of:

- Developing input parameters
- Calculation effort

Path Forward

- Example computations for various values of Vs, distance to source, and magnitude. Offset of decrease of amplitude and increase of period with distance.
- Compare some examples to M-O case.
- Develop model & description (Part 3 paper) for balloting in IT7

End