Modeling Acoustic Interface Wave Dispersion Using COMSOL

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COMSOL CONFERENCE
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Outline

- Motivation
  - Geo-acoustic Parameters
  - Scholte Waves
  - Experiment
- COMSOL Modeling
  - Geometry
  - PML considerations
- Post-processing
  - Spatial Transform
  - Comparison with data

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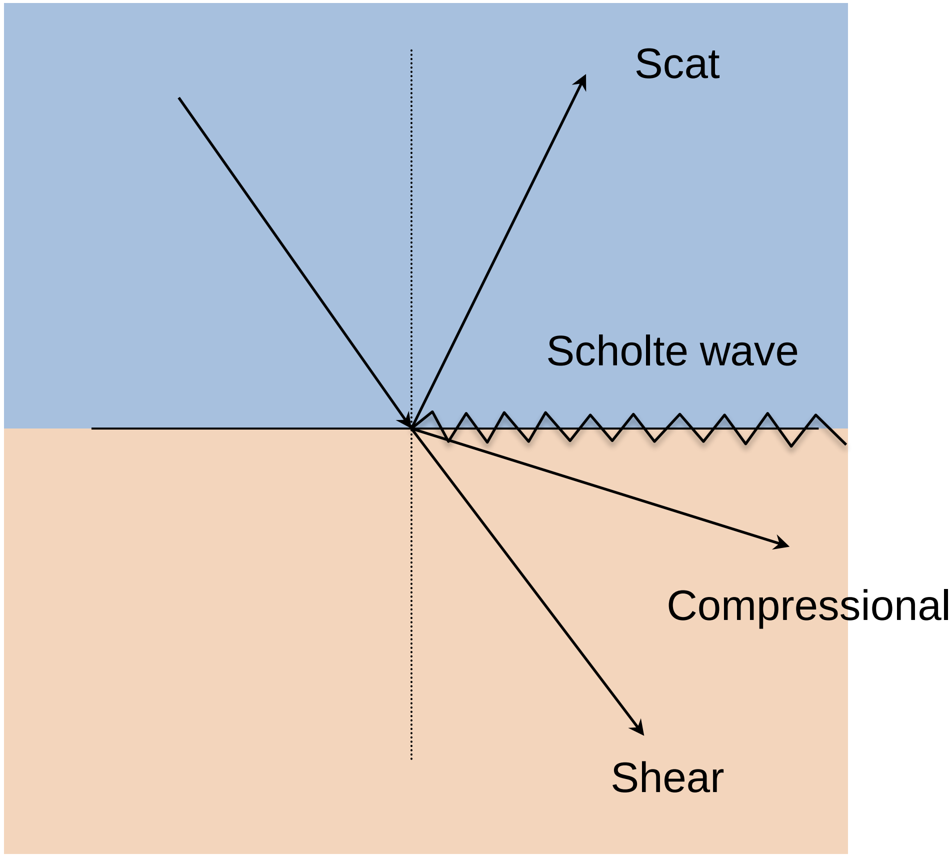
Motivation

- Require accurate models of sediments in shallow water environments
- Compressional wave speed and density are easy to measure
- Need to incorporate shear waves in sediments for accurate numerical modeling
- Shear wave speed hard to measure due to high attenuation.
- Direct relationship between shear wave and Scholte wave
  - Scholte wave measurements → shear wave speeds

Motivation



- Scholte wave phase speed is ~90% of the shear wave speed
- Elliptical particle motion
- No low frequency cutoff

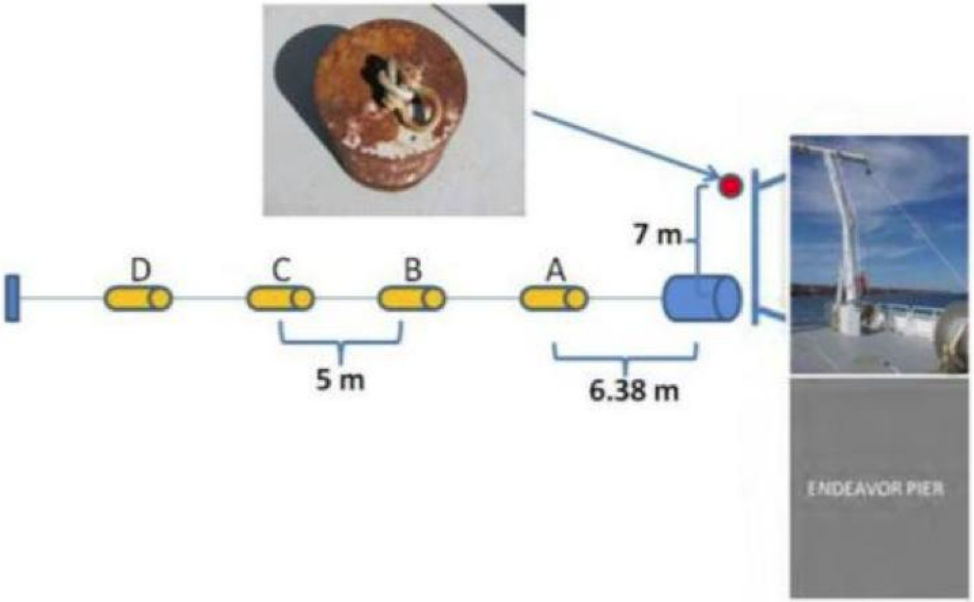
Motivation

- Scholte wave phase speed is frequency-independent in an elastic half-space.
  - For a seafloor composed of layered sediments, Scholte wave phase speed is dispersive.

- Can use Scholte wave dispersion to invert for shear wave speeds in each sediment layer.
  - Dynamic stiffness matrix inversion model

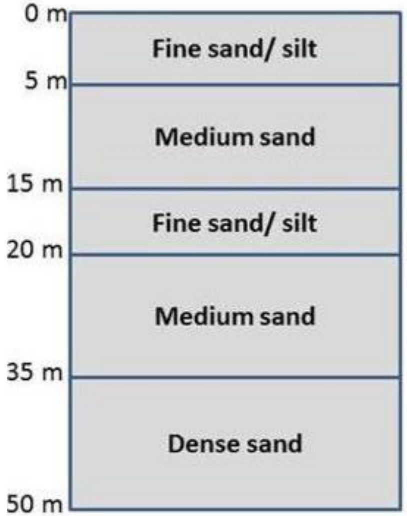
Experiment

Plan view:



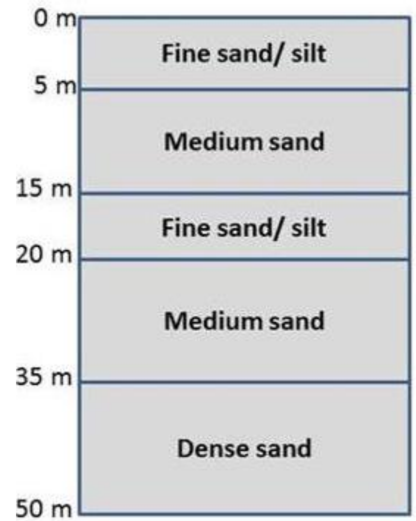
G. Potty and J. Miller. Measurement and modeling of Scholte wave dispersion in coastal waters. In Proc. of Third Int. Conf. on Ocean Acoustics, Beijing, China, 21-25 May 2012.

Experiment



Medium	Layer thickness (m)	c_p (m/s)	c_s (m/s)	ρ (kg/m^3)
Water	6	1540	-	1000
Sediment				
Layer1	2	1600	45	1650
Layer 2	4	1650	100	1840
Layer 3	7	1600	170	1710
Layer 4	9	1650	250	1940
Half-space	∞	1836	380	2034

Experiment



Core sample analysis

Medium	Layer thickness (m)	c_p (m/s)	c_s (m/s)	ρ (kg/m^3)
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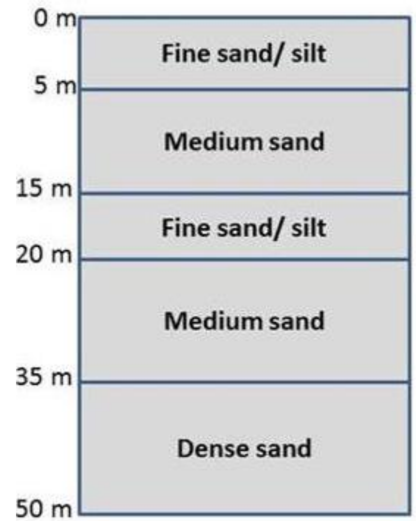

Dynamic stiffness matrix inversion

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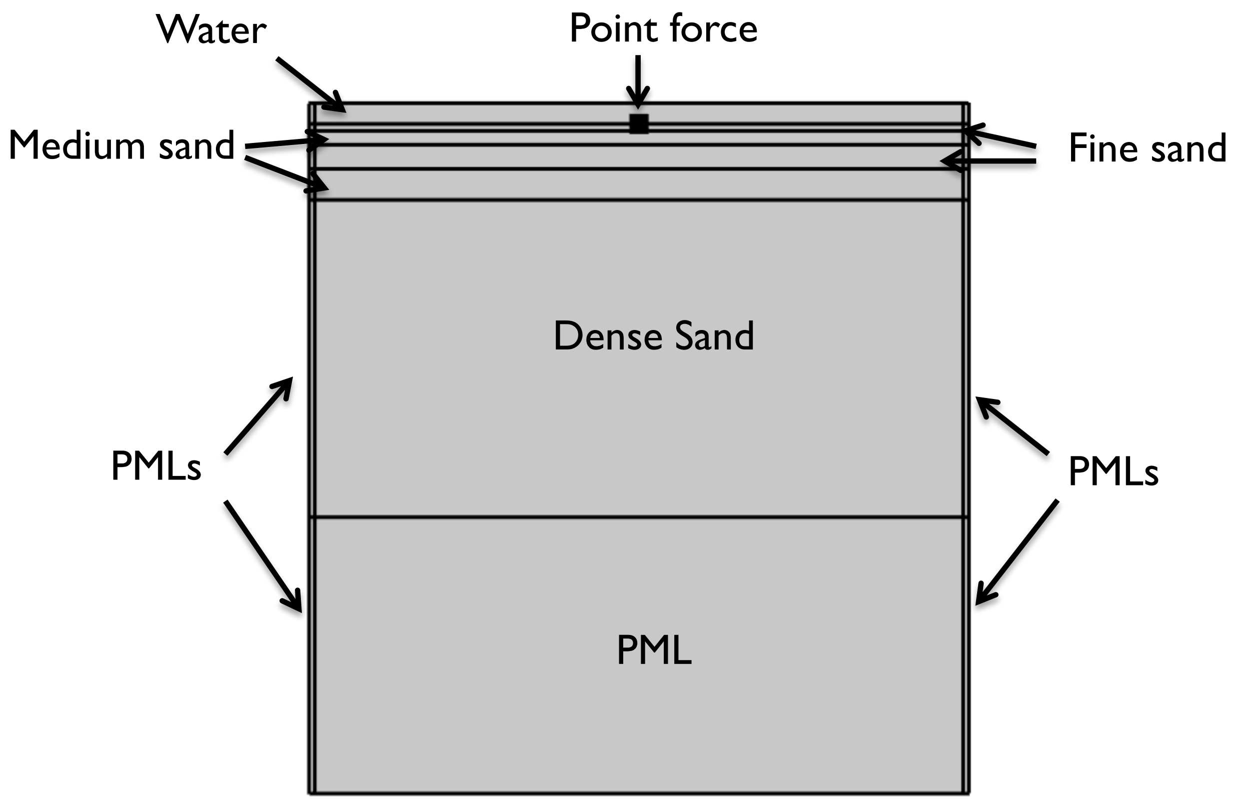
Modeling



- Pressure Acoustics, Frequency Domain: Water
- Solid Mechanics, Frequency Domain: Sand layers

Modeling

- Interface conditions:

$$d = \nabla\Phi + \nabla \times \Psi$$

Total particle displacement in elastic

$$\frac{1}{\rho\omega^2}\frac{\partial p}{\partial n} = \nabla\Phi \cdot \hat{n} + (\nabla \times \Psi) \cdot \hat{n}$$

Continuity of vertical displacement

$$p = \sigma_n$$

Continuity of normal stress

Modeling

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Continuity of vertical displacement

$$p = \sigma_n$$

Continuity of normal stress

Pressure Acoustics: Normal acceleration node

Solid Mechanics: Boundary load node

Modeling

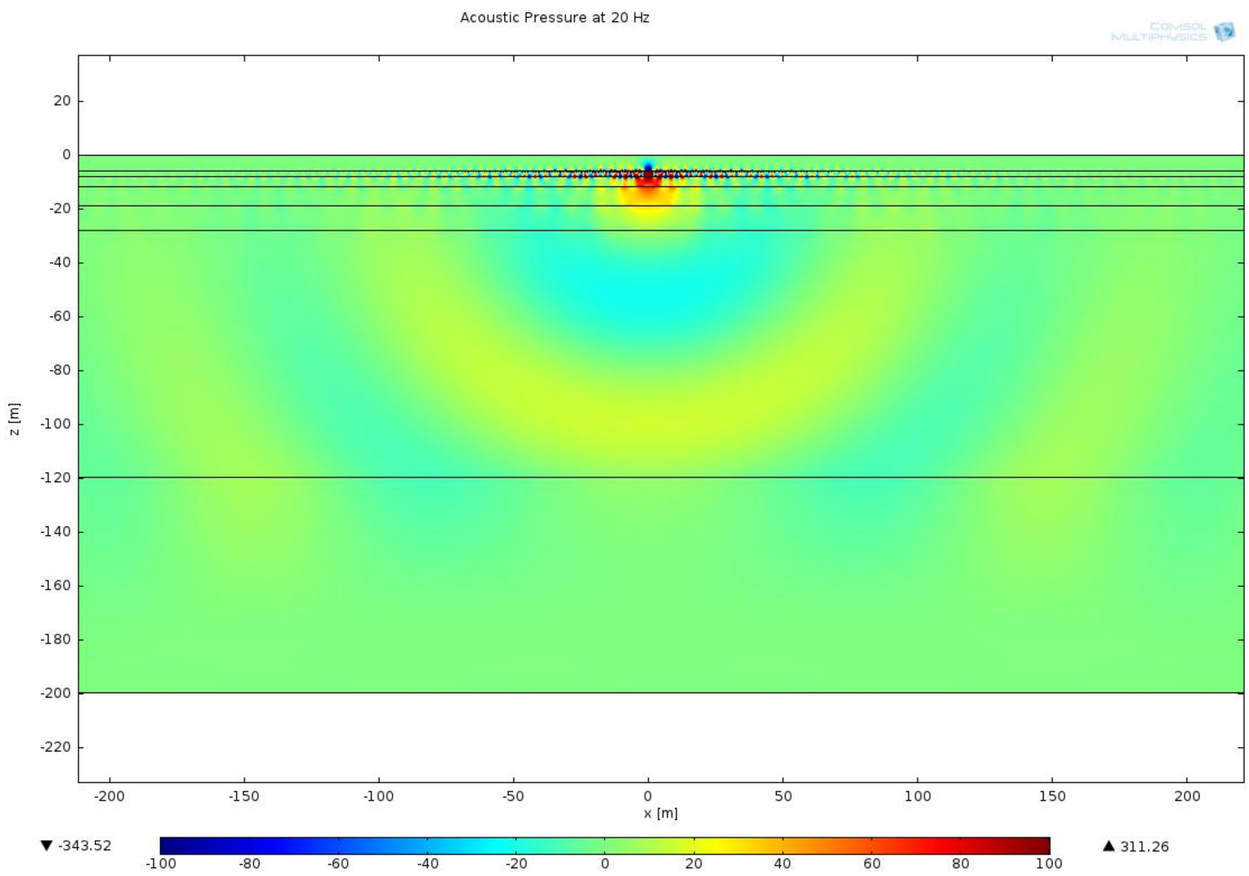
- Source
  - Solid Mechanics: point load node
  - Mass of weight x gravitational acceleration
- Mesh criterion
  - Based on smallest wavelength (shear)
  - Maximum element size: $\lambda/8$

Modeling

- PMLs do not effectively absorb Scholte waves and un-attenuated shear waves in elastic media.

- PML considerations:
  – Attenuate shear wave and use PMLs to only absorb compressional wave.
  – Make computational domain long enough so the Scholte wave is mostly dissipated at the boundary

Modeling



Acoustic Pressure at 20 Hz
COMSOL MULTIPHYSICS
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
z [m]
-200
-150
-100
-50
0
50
100
150
200
x [m]
▼ -343.52
-100
-80
-60
-40
-20
0
20
40
60
80
100
▲ 311.26

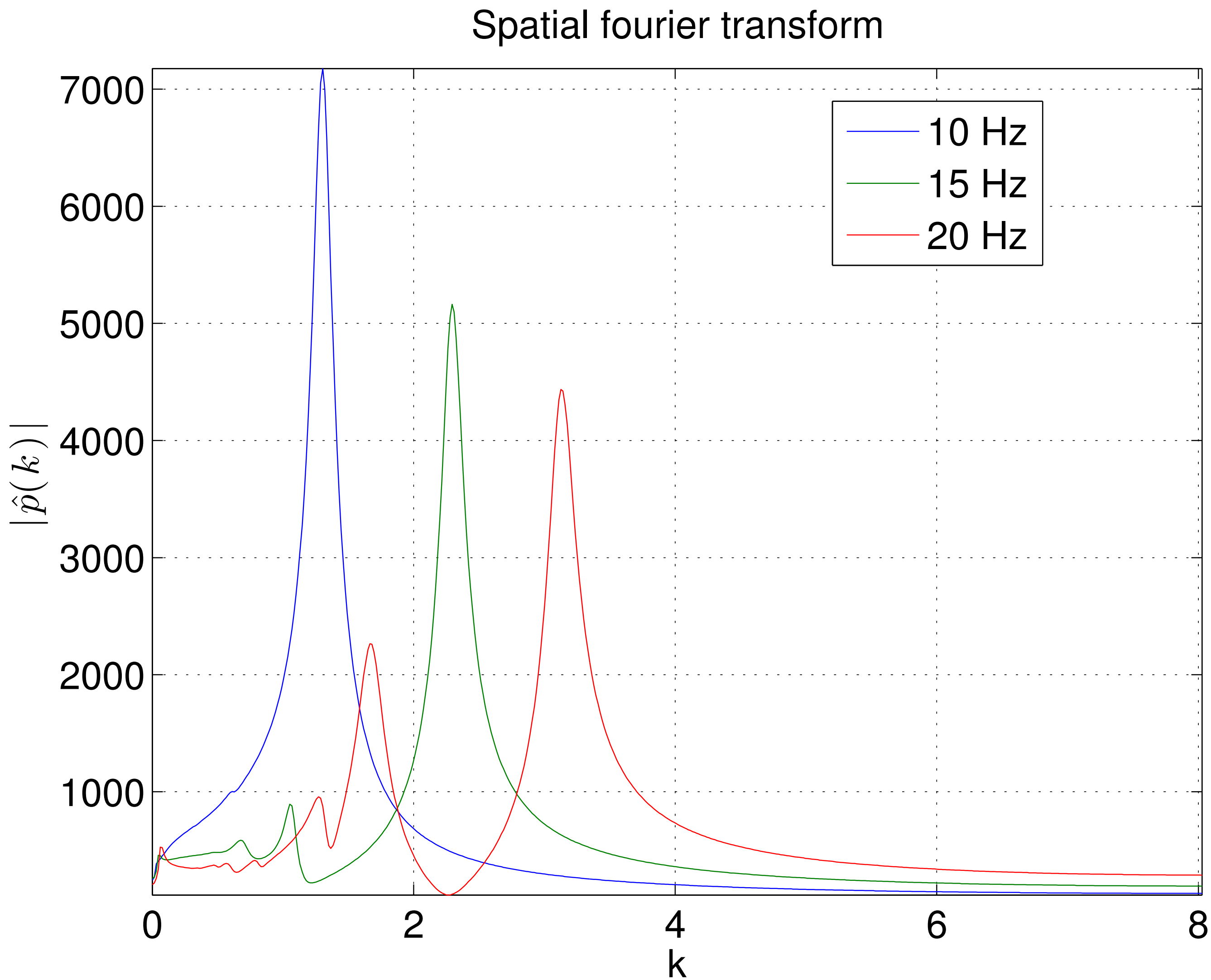
Post-processing

- Spatial Fourier Transform

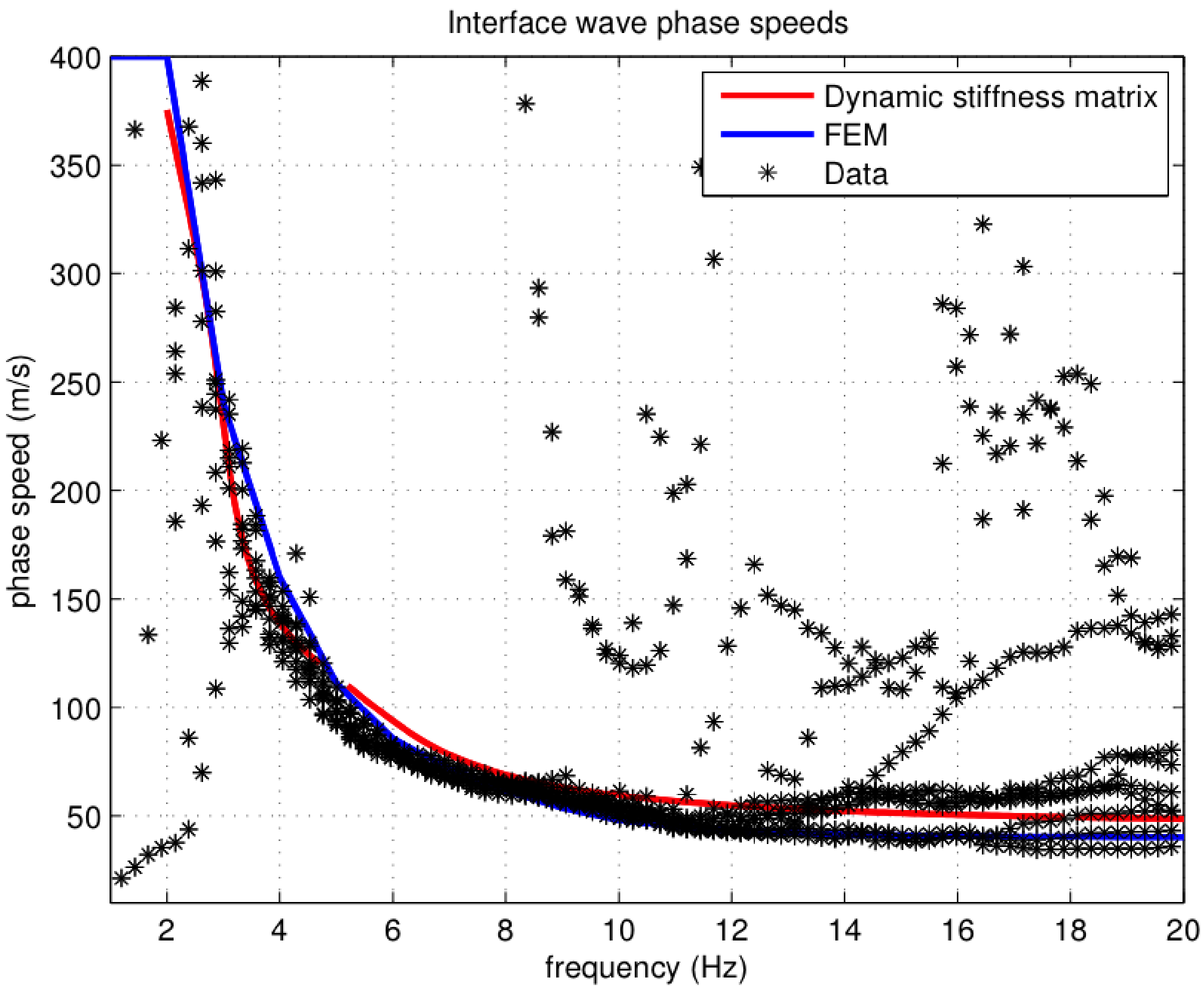
$$\hat{p}(k) = \int_{-\infty}^{\infty} p(x) e^{-i2\pi kx} dx$$

$$c_{ph} = \frac{2\pi f}{k}$$

Post-processing



Post-processing



Conclusion

- COMSOL used to model experiment at Narragansett Bay, RI.
- A spatial Fourier transform was used to calculate phase speeds
- Computed phase speeds agree well with measured data.