Application and Modification of Design Formulae for Nonimpulsive Wave Forces on Elevated Coastal Structures

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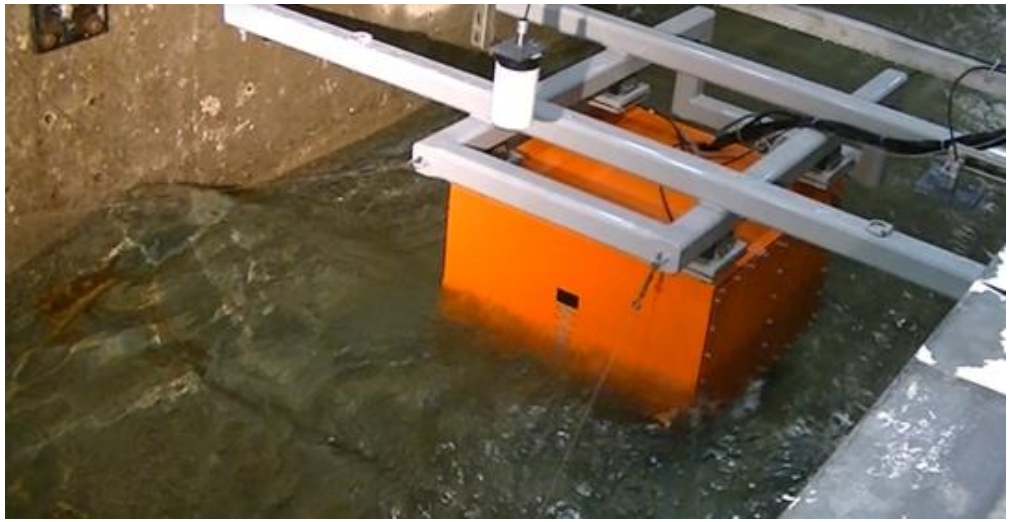

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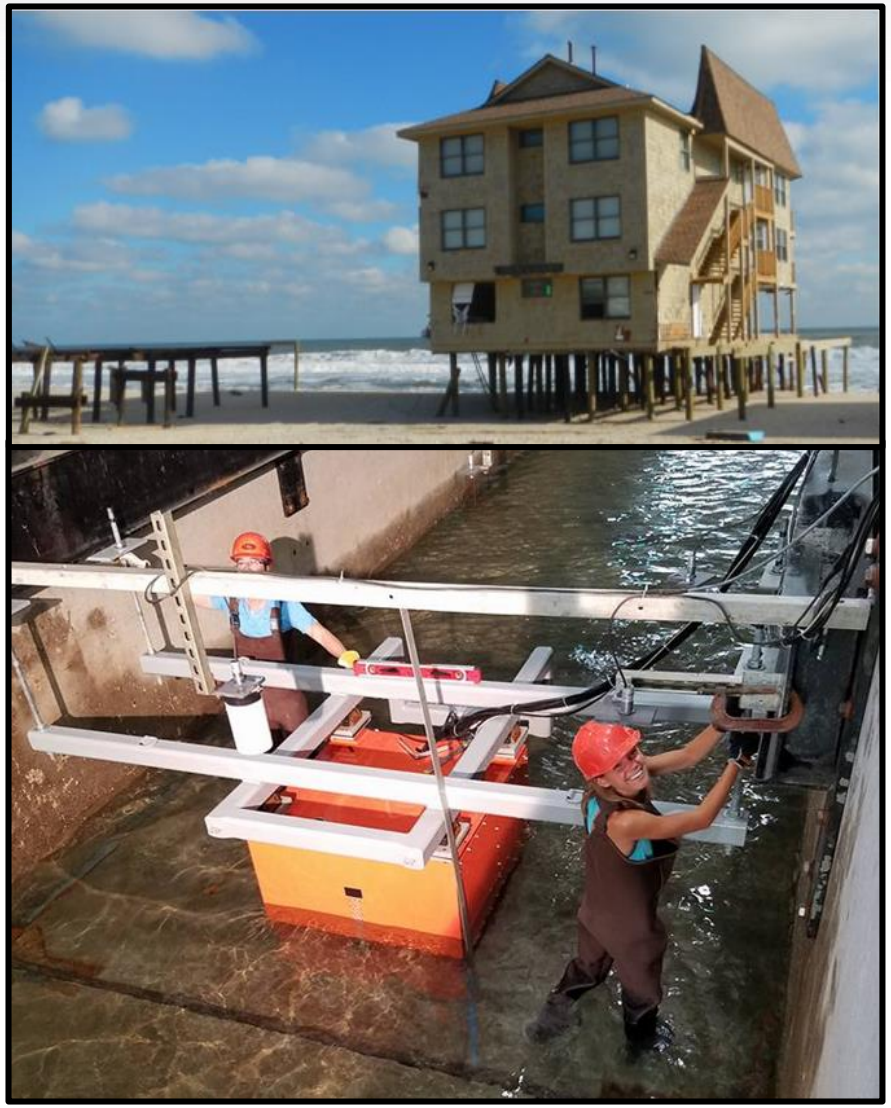
Outline

1. Introduction and Motivation
2. Background
   a) ASCE7 Design Formulae
   b) Modified Goda Formulae
3. Experimental Methods
4. Results
5. Conclusions and Implications for Design



Bolivar, TX, USA

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ASCE7 Chapter 5: Flood Loads

Nonbreaking/Broken Waves: Superposition

$$F_{Hydrostatic}/B=\gamma_w(DFE+0.3m)^2$$

$$F_D/B=1/2\rho V^2 C_D(0.3+H/2+d_s)$$

Nonbreaking/Broken Waves: Equivalent Surcharge

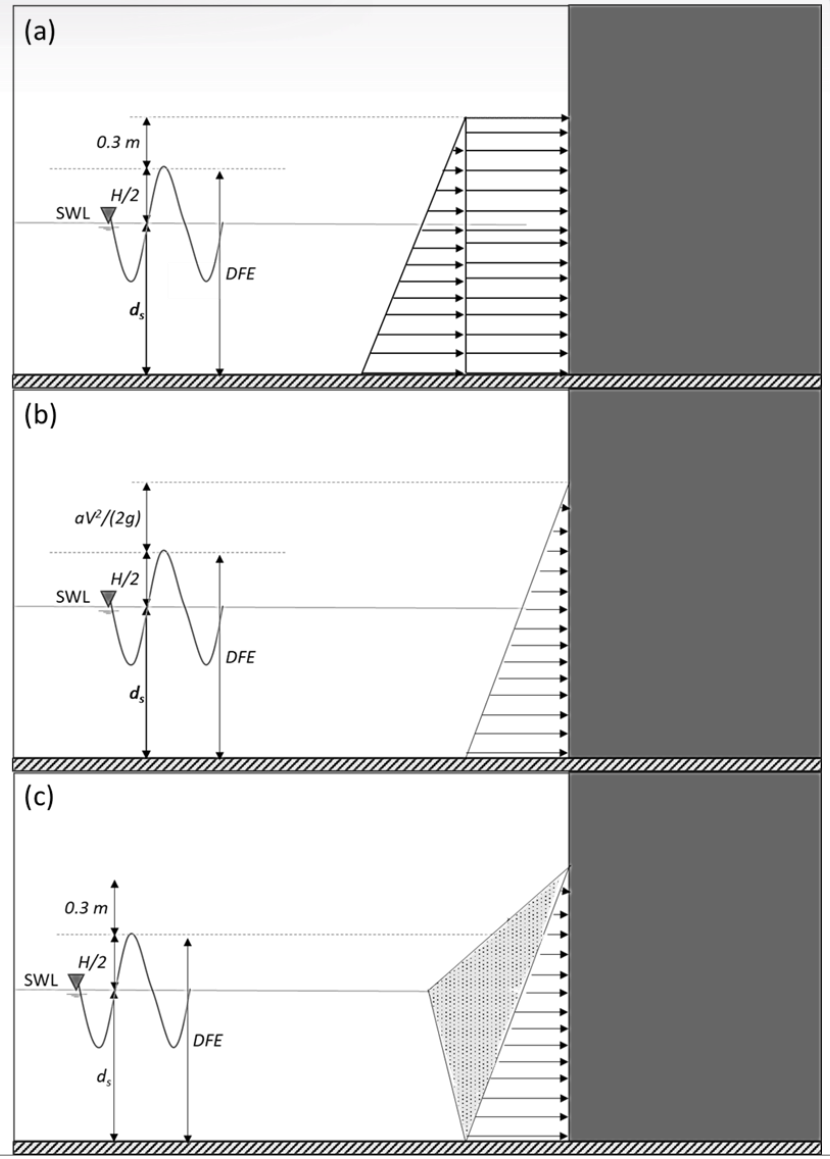
$$d_h=aV^2/(2g)$$

$$F_{Combined}/B=\gamma_w(DFE+d_h)^2$$

Impulsive Breaking Waves:

$$P_{max}=C_P\gamma_w d_s+1.2\gamma_w d_s$$

$$F_t/B=1.1C_P\gamma_w d_s^2+2.4\gamma_w d_s^2$$



Modified Goda Methodology

- Originally derived for vertical breakwater, nonimpulsive waves
- Takahashi et al. (1994) and others: coefficients for impulsive breaking wave pressures
- Shore-normal waves, vertical structures on a flat bathymetry:

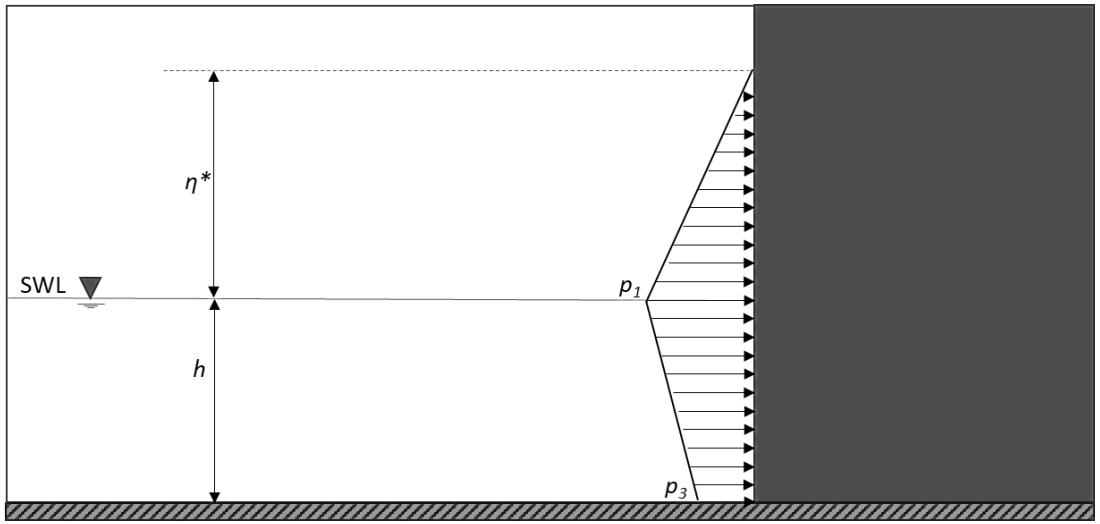
$$\eta^* = 1.50 H_{max}$$ Elevation of zero pressure

$$p_1 = (\alpha_1)\rho g H_{max}$$ Pressure at SWL

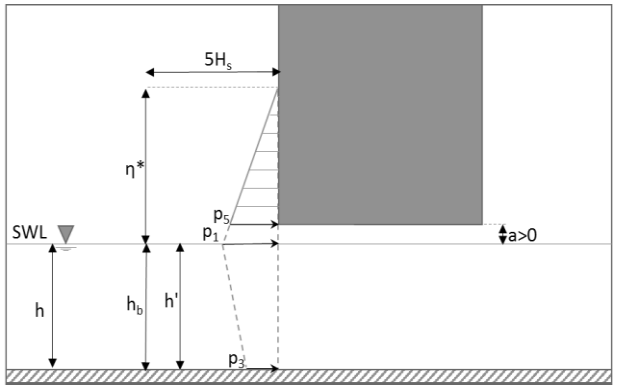
$$p_3 = \frac{p_1}{\cosh\left(\frac{2\pi h}{L}\right)}$$ Pressure at bed

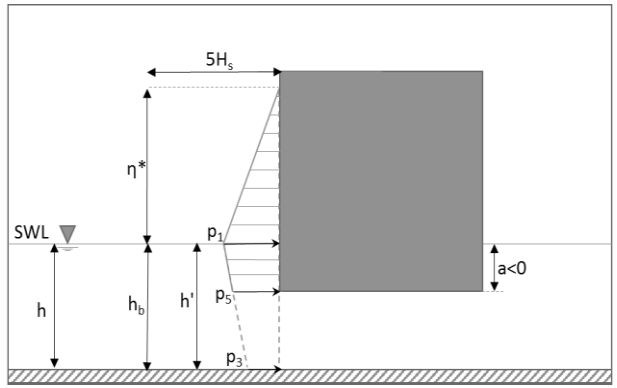
$$\alpha_1 = 0.6 + \frac{1}{2}\left[\frac{4\pi h/L}{\sinh(\frac{4\pi h}{L})}\right]^2$$ Wave pressure coefficient

h=water depth
H_{max}= design wave height
L= wavelength



- Wiebe et al. (2014): Modified for elevated structures





Large-Scale Physical Model

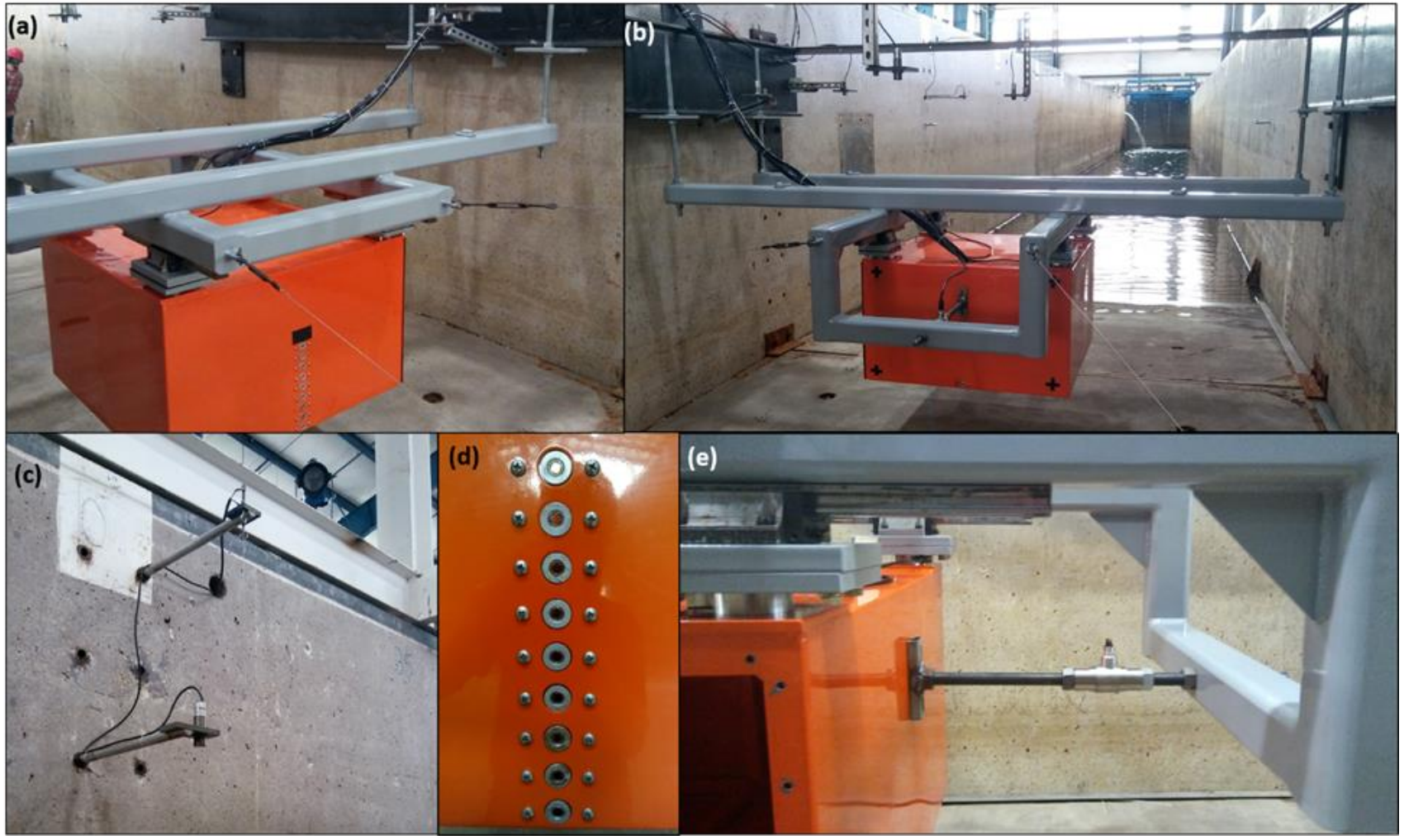
- Physical Models-
  - Understand wave-structure interaction in ideal situations, known inputs
  - Validate numerical models for benchmarking and generalization
- Elevated Structure Experiment: July, 2016-March, 2017, Oregon State University Large Wave Flume
- ~1:10 length scale, Fr number similitude

Experimental Goal:

Characterize horizontal and vertical wave-induced pressures and loads on elevated structures for various wave/surge conditions

Instrumentation

- Wire resistance wave gauges
- Ultrasonic wave gauges
- Horizontal and vertical load cells
- Pressure transducers

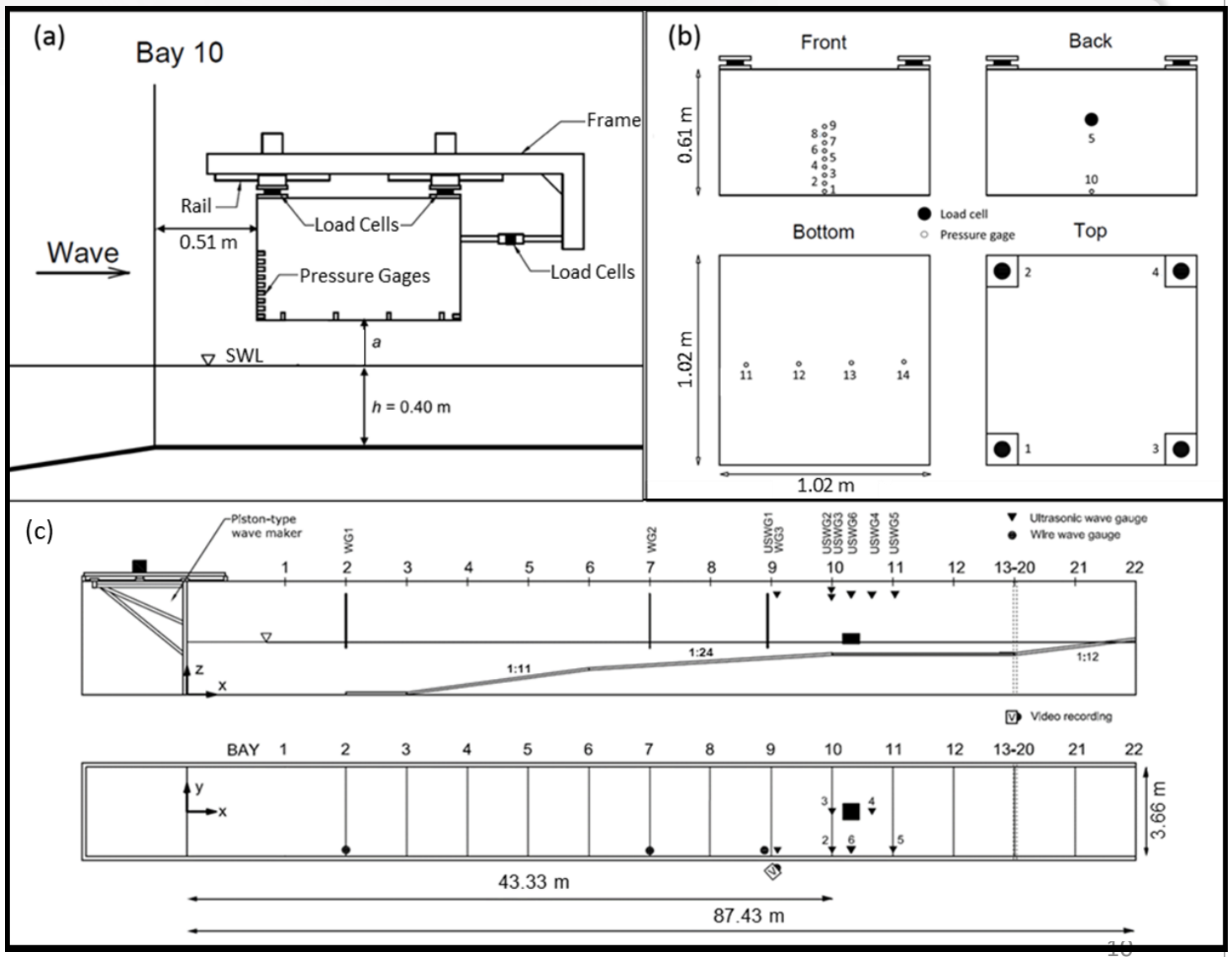


Set-up

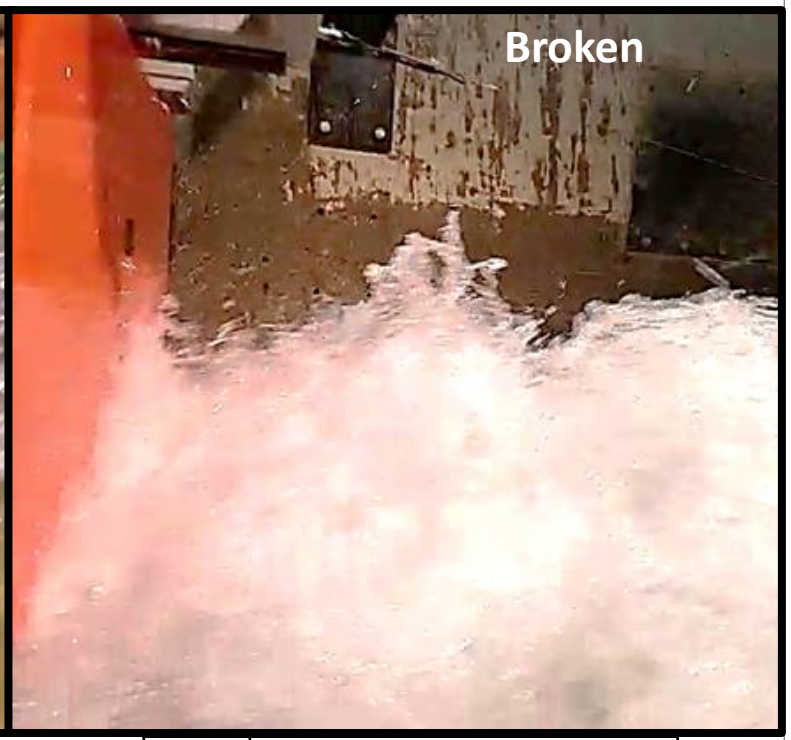
- Sampling Rate= 500 Hz

Case	a (m)	z(m)
a_0	-0.40	0.01
a_1	-0.39	0.10
a_2	-0.20	0.20
a_3	-0.10	0.30
a_4	-0.05	0.35
a_5	0.00	0.40
a_6	0.05	0.45
a_7	0.10	0.50
a_8	0.20	0.60
a_9	0.28	0.68

	Test 1 (no specimen)		Tests 2-3 (with specimen)	
Instrument	**x (m)**	**y (m)**	**x (m)**	**y (m)**
wg1	14.17	-1.39	14.17	-1.39
wg2	32.44	-1.38	32.44	-1.38
wg3	43.43	-1.38	39.57	-1.38
uswg1	43.14	-1.38	39.70	-1.38
uswg2	46.81	-1.30	43.18	-1.37
uswg3	50.45	-0.11	43.22	-1.38
uswg4	57.78	-0.01	45.68	-1.38
uswg5	61.43	-1.28	47.09	-1.37
uswg6	76.09	-1.28	44.37	-1.35



Wave Conditions



Exp.	$\bar{H}$ (m)	$\bar{T}$ (s)	*h (m)*
1	0.12	4.10	0.40
2	0.32	4.10	0.40
6	0.17	2.52	0.40

Exp.	$\bar{H}$ (m)	$\bar{T}$ (s)	*h (m)*
3	0.32	4.10	0.40
7	0.26	2.98	0.40
8	0.34	3.28	0.40

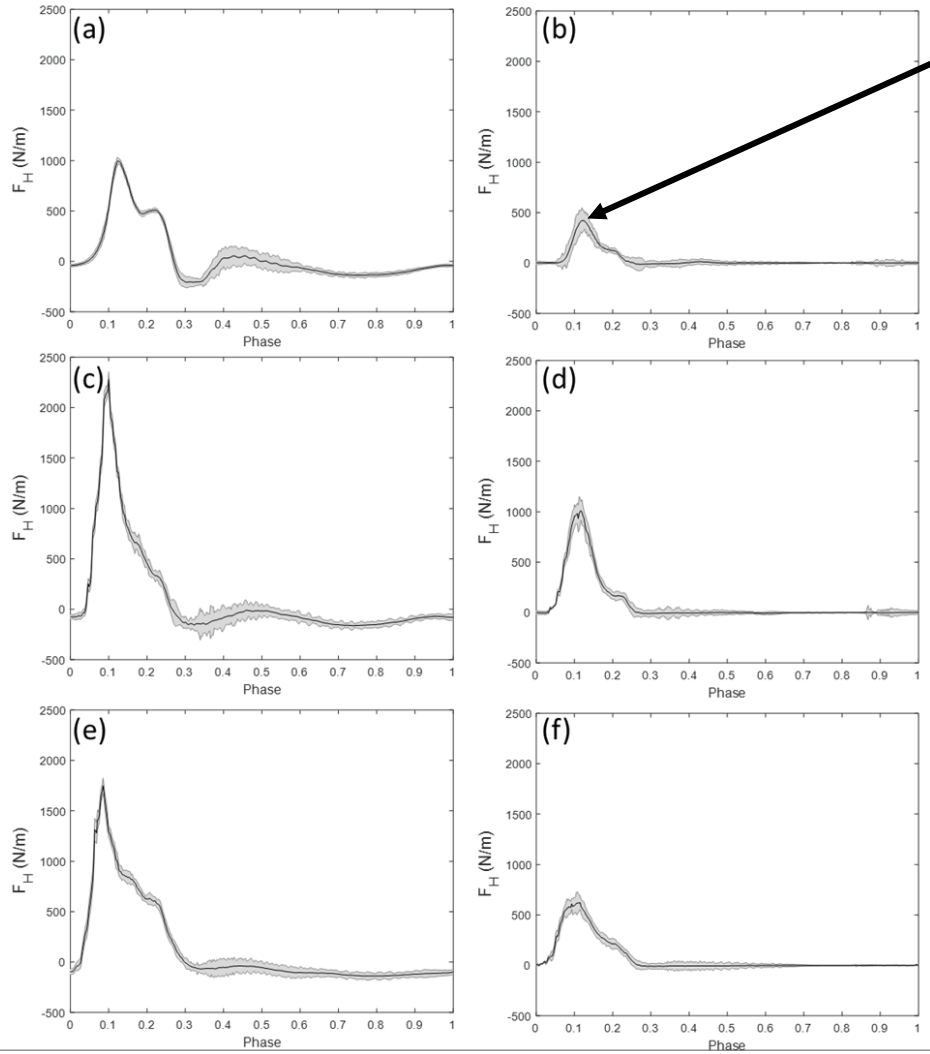
Exp.	$\bar{H}$ (m)	$\bar{T}$ (s)	*h (m)*
4	0.27	4.10	0.40
5	0.26	4.10	2.15
9	0.23	4.68	2.15
10	0.18	5.04	2.15

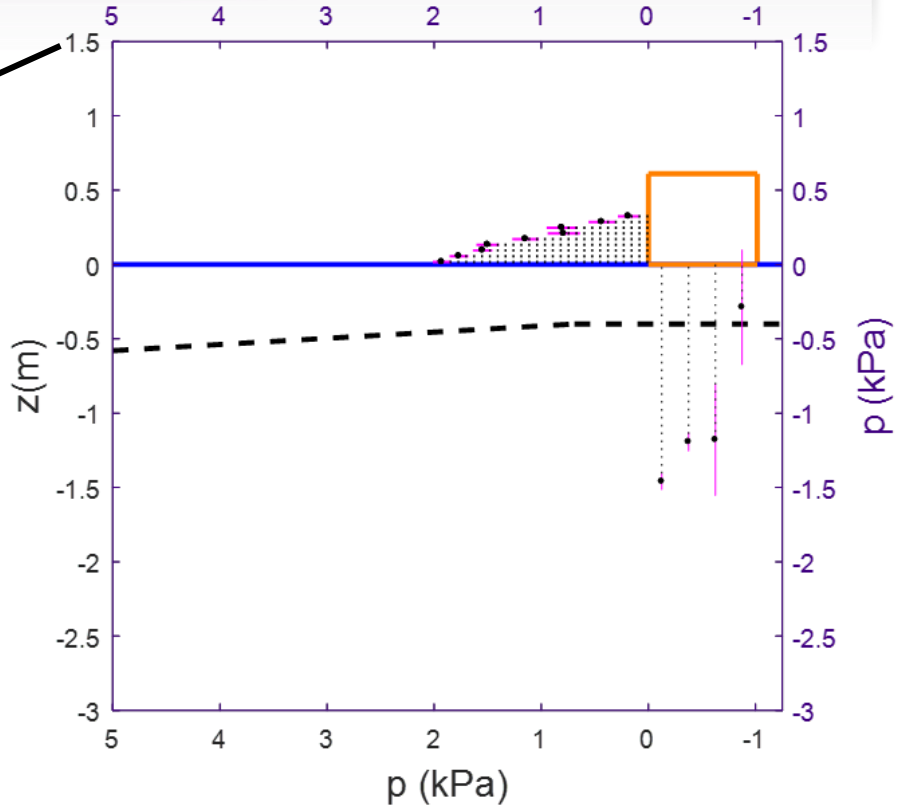
Ensemble Averaging

Nonbreaking

Breaking

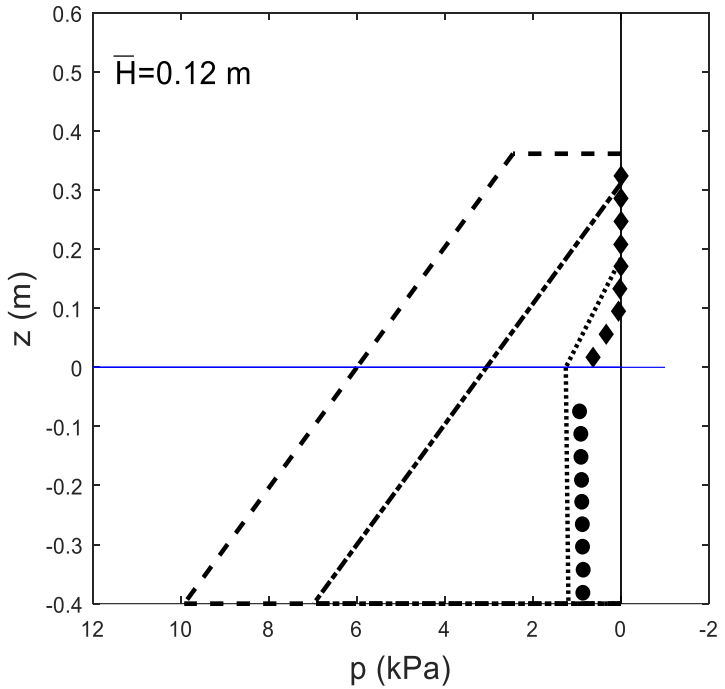
Broken

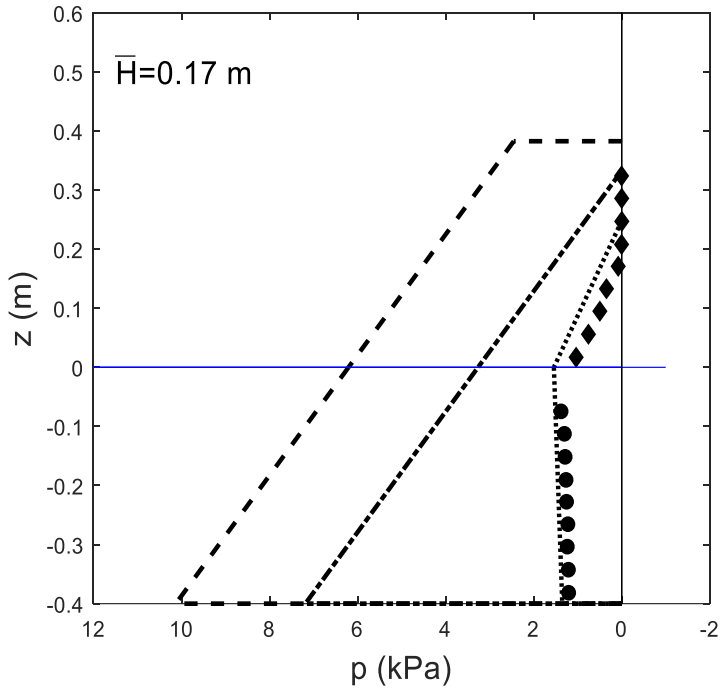


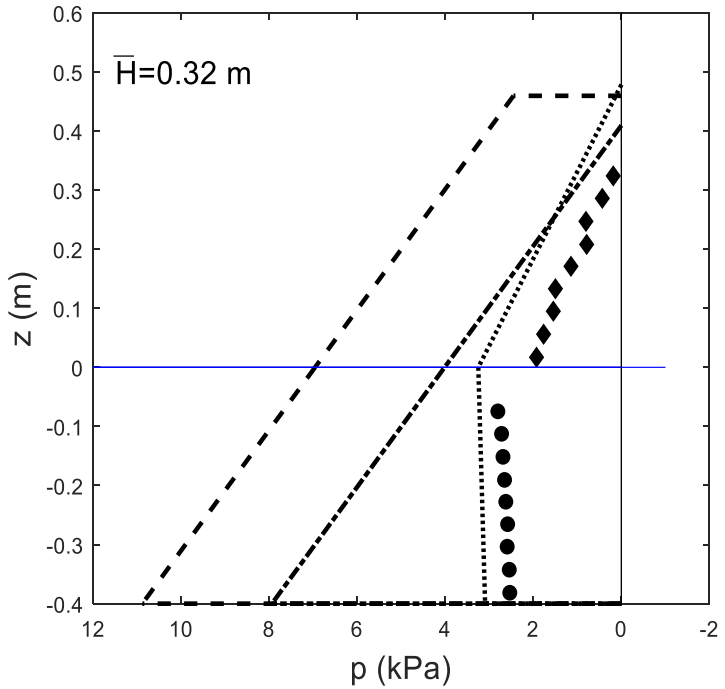


$\bar{H}$ (m)	$\bar{T}$ (s)	h (m)	a (m)
0.32	4.10	0.40	0.0

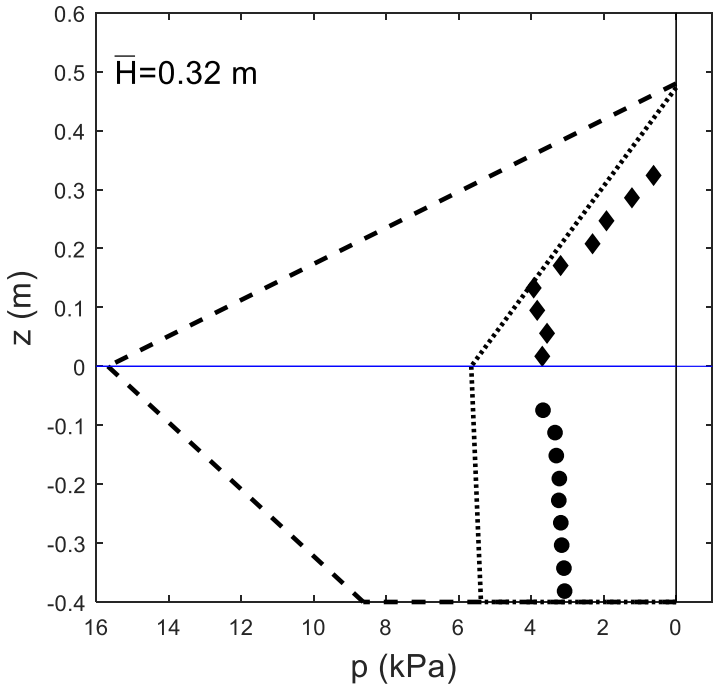
Comparison of Predicted Pressure Distributions and Measured Pressures: Nonbreaking

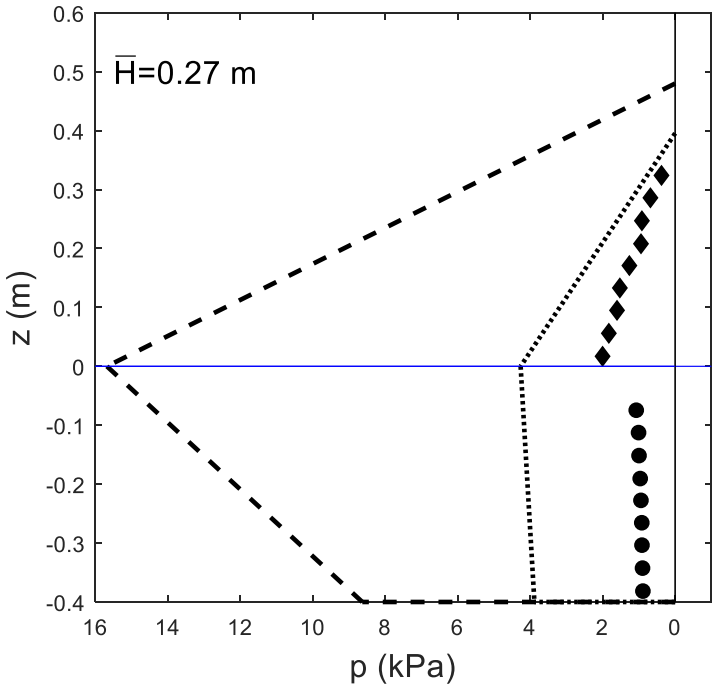


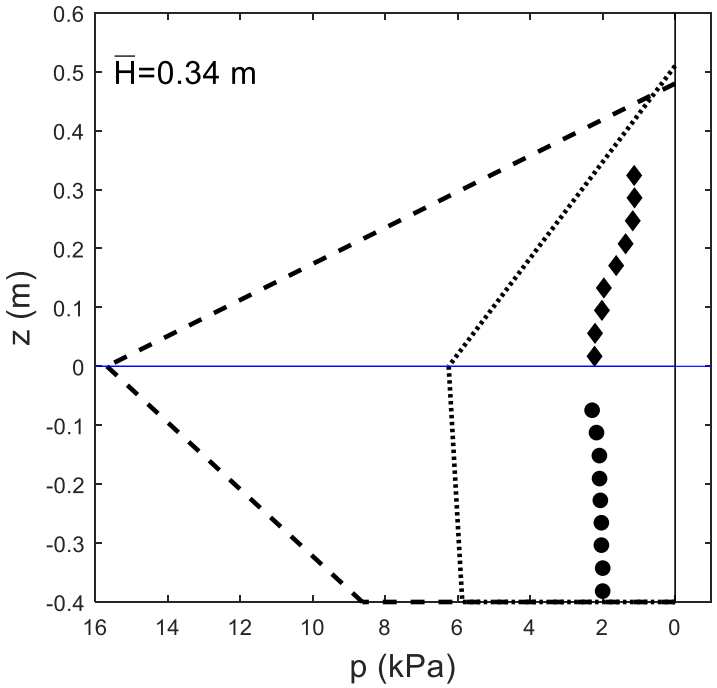




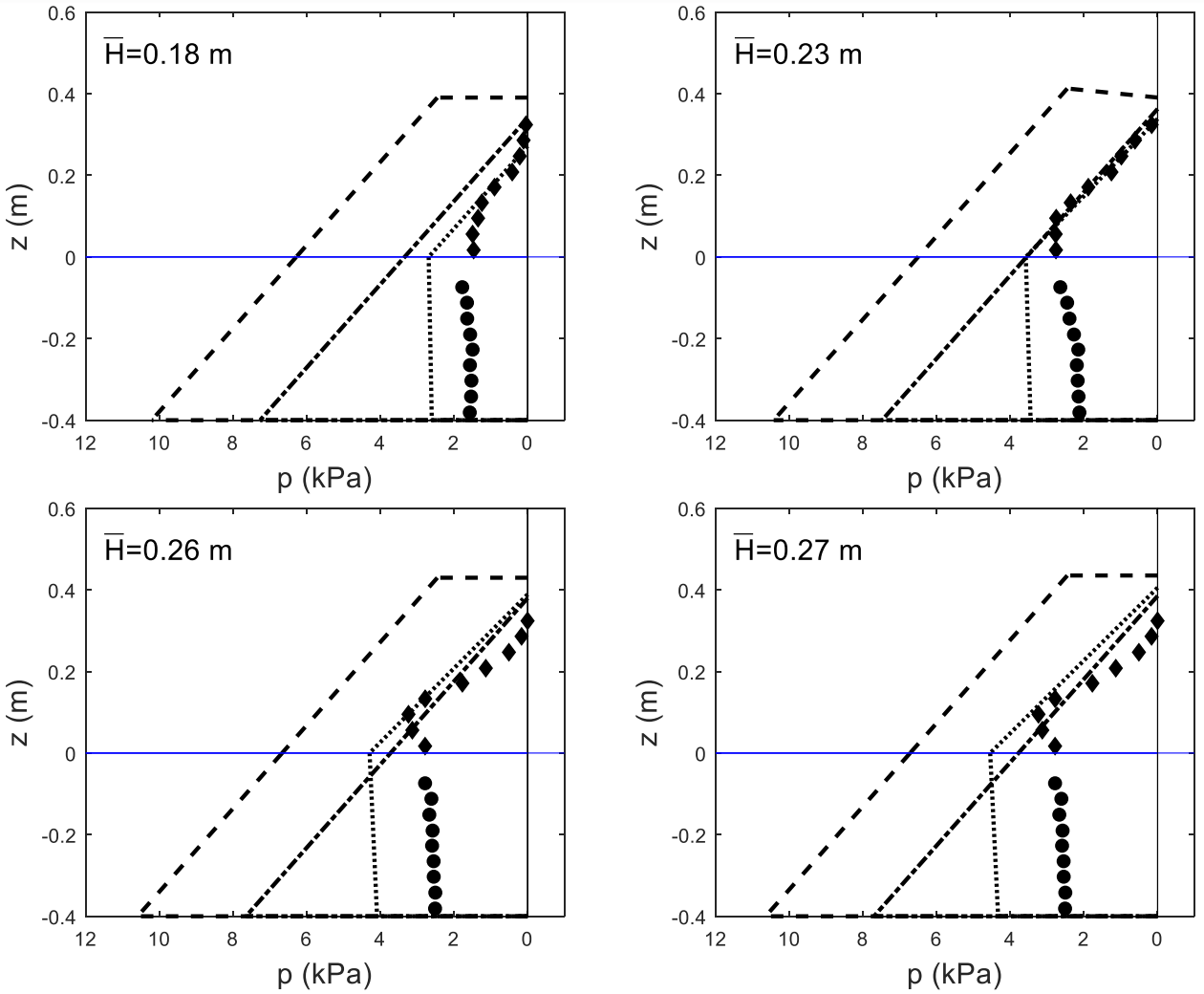
Comparison of Predicted Pressure Distributions and Measured Pressures: Breaking



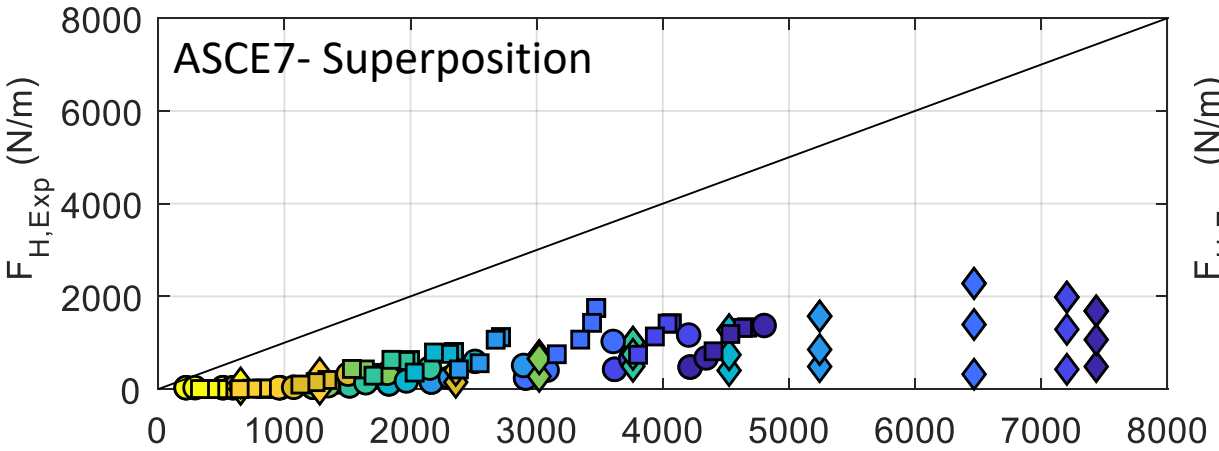


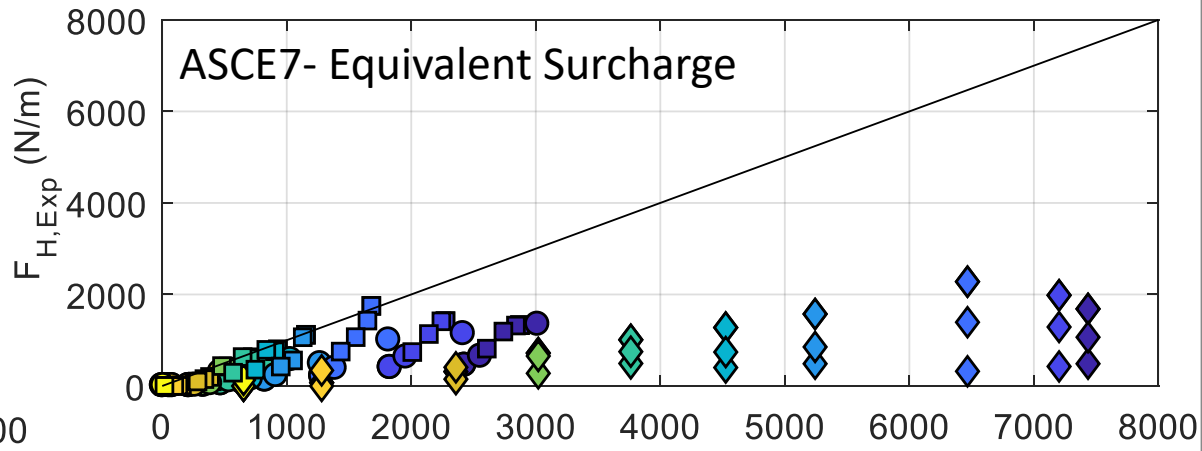


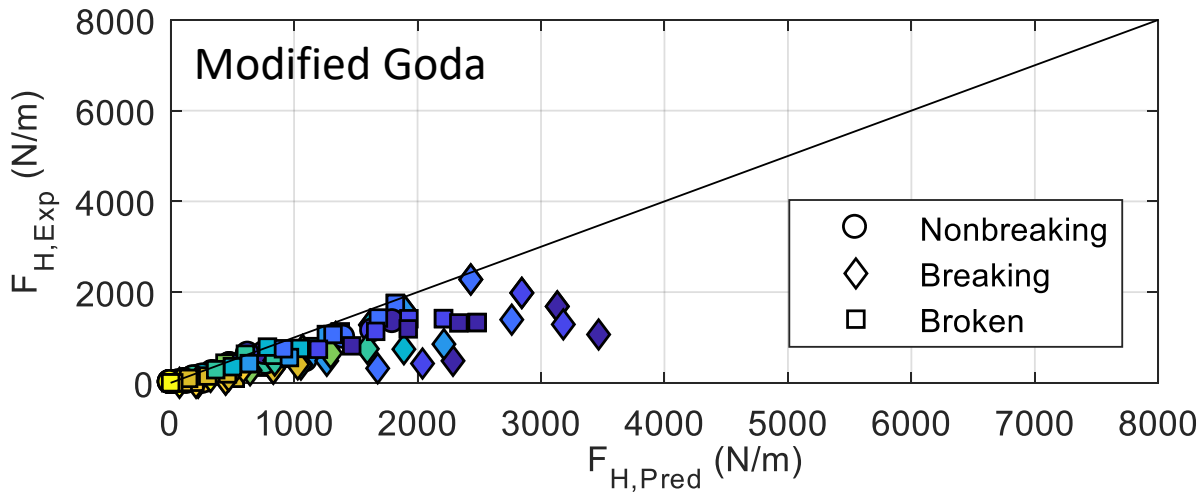
Comparison of Predicted Pressure Distributions and Measured Pressures: Broken



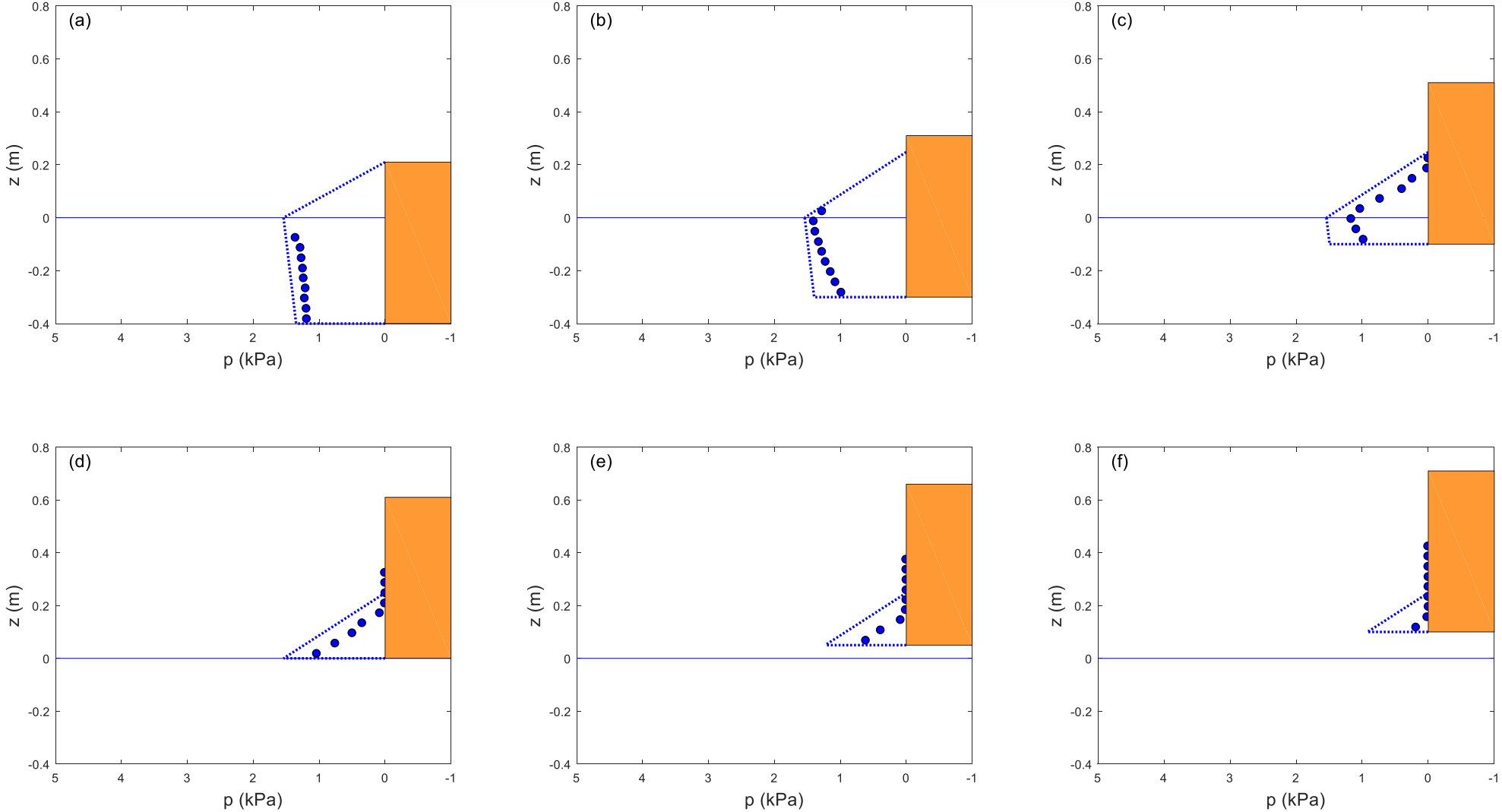
Comparison of Predicted and Measured Forces





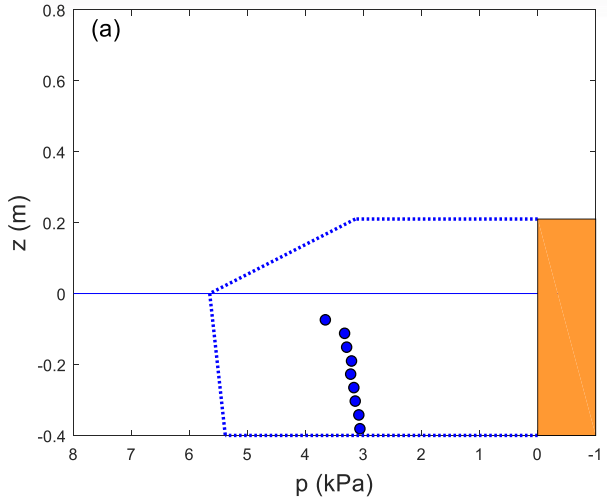


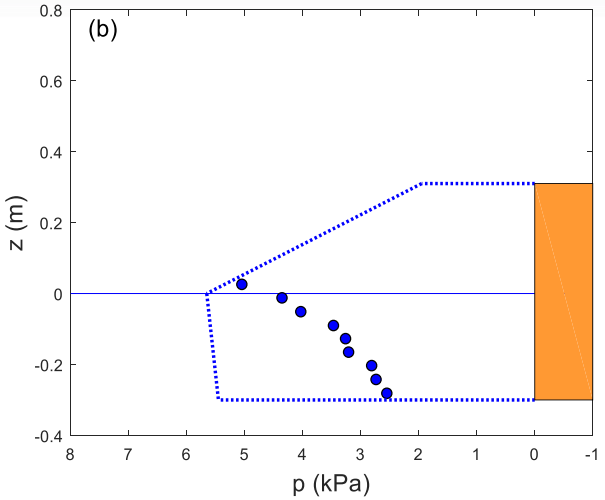
Application to Elevated Structures- Nonbreaking

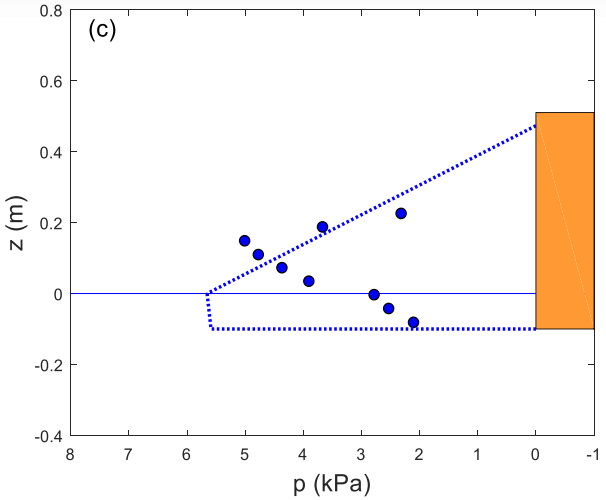


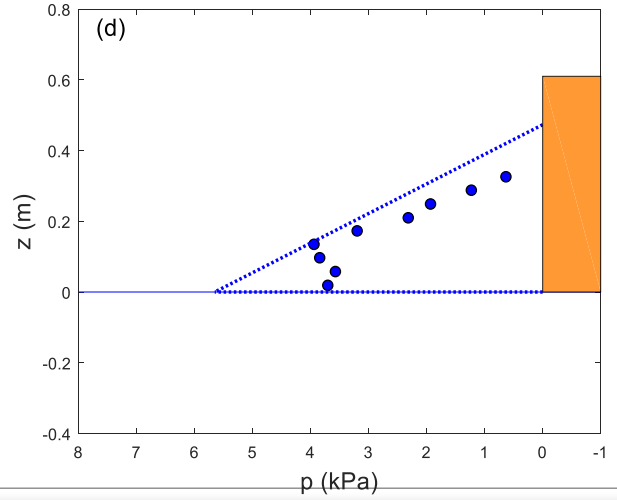
$\bar{H}$ =0.17 m
$\bar{T}$ =2.52 m

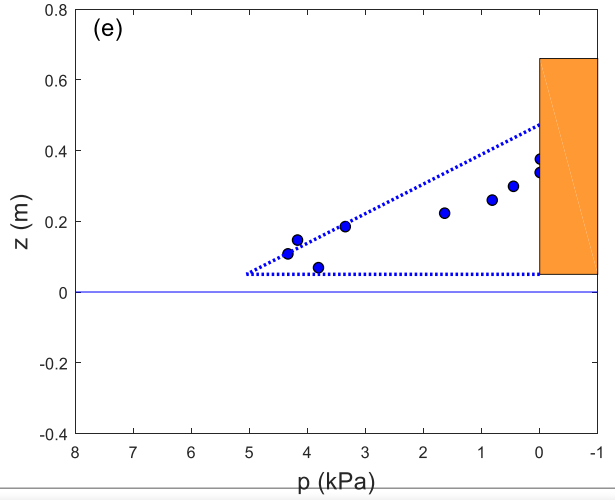
Application to Elevated Structures- Breaking

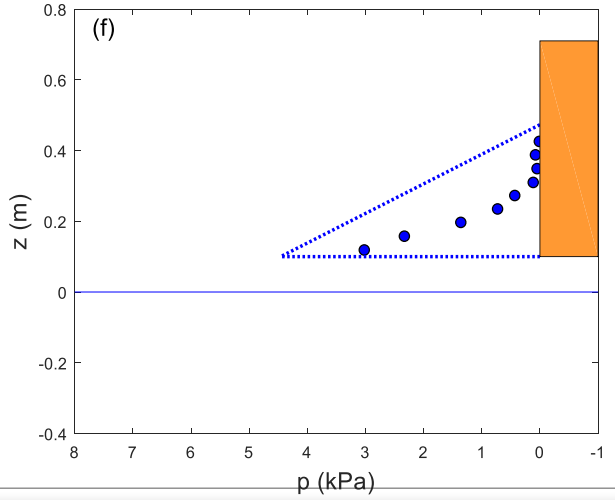






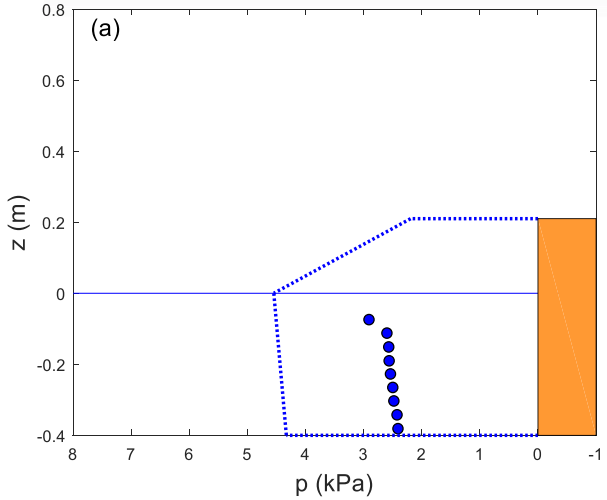


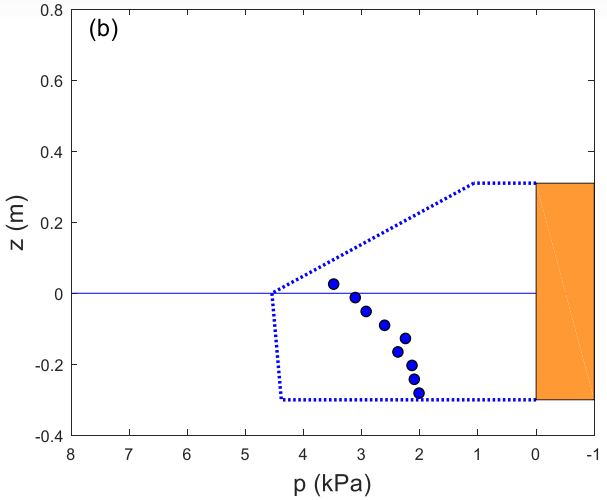


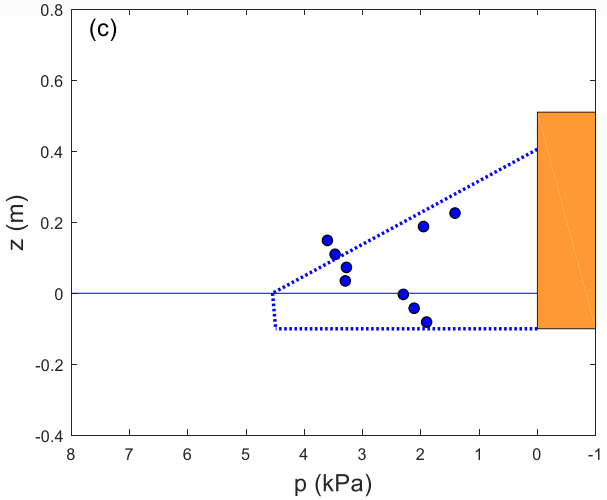


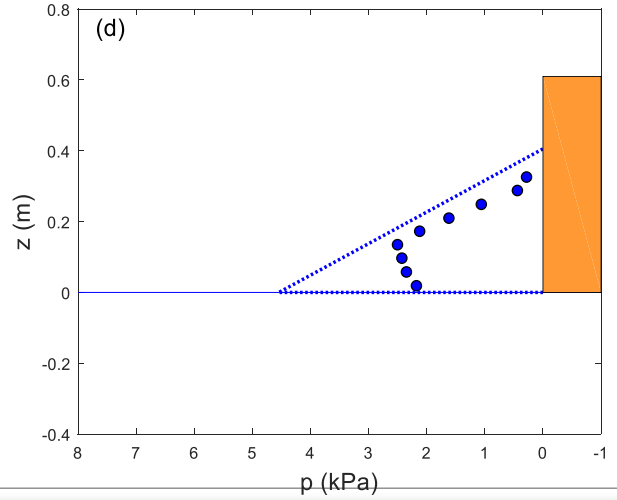
$\overline{H}$ =0.32 m
$\overline{T}$ =4.10 m

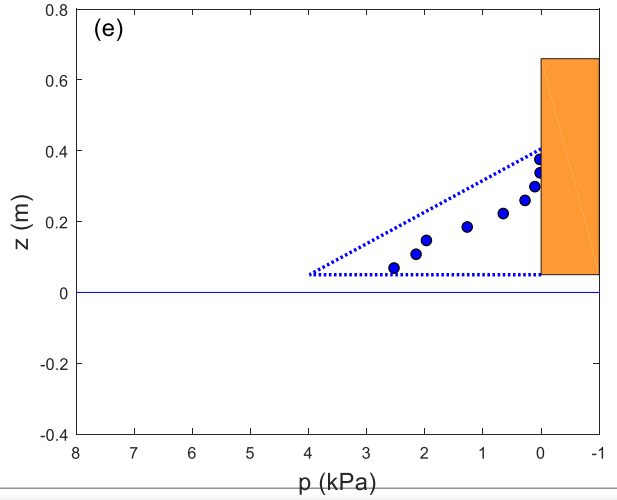
Application to Elevated Structures- Broken

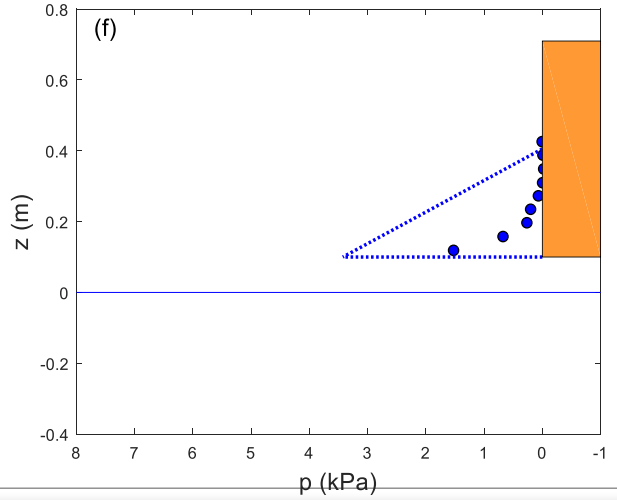












$\bar{H}$ =0.27 m
$\bar{T}$ =4.10 m

Conclusions

- Large scale physical model- inform standards for wave loads on elevated structures
- Modified Goda equations- perform well for nonbreaking, breaking, and broken waves
- Need to consider vertical force
- ***Multidisciplinary efforts needed to find creative solutions***

Thank you for your kind attention!