Session 8

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Wave Forces on Bridges

Topic Description

Wave Forces on Bridges

This presentation outlines the wave force on bridge span research that is currently underway at the University of Florida. An instrumented model bridge span is being subjected to: 1) monochromatic and 2) random waves and the forces and moments measured. The results are being used to test/calibrate/verify theoretical equations for predicting horizontal and vertical loads on bridge spans.

Speaker Biography

Max Sheppard is President of Ocean Engineering Associates, Inc. (OEA, Inc.) and Professor Emeritus in the Civil and Coastal Engineering Department at the University of Florida. His areas of expertise include: bridge scour, coastal hydraulics, sediment transport, coastal structures, and wave loading on coastal and offshore structures.

Wave Forces on Bridges

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Outline

- Wave / Surge Induced Bridge Failures
- Waves and Wave Induced Forces
- Wave Force Research
  - Theoretical
  - Wave tank tests
  - Field verification
- Summary

Motivation

- Recent Bridge Failures Attributed to Storm Surge/Wave Induced Failures
  - I-10, Escambia Bay (Pensacola, FL)
  - US-90, Biloxi Bay (Biloxi, MS)
  - US-90, Saint Louis Bay (Bay Saint Louis, MS)
  - I-10, Lake Pontchartrain (New Orleans, LA)

Bridge Failures

Pensacola, FL

Bay Saint Louis, MS

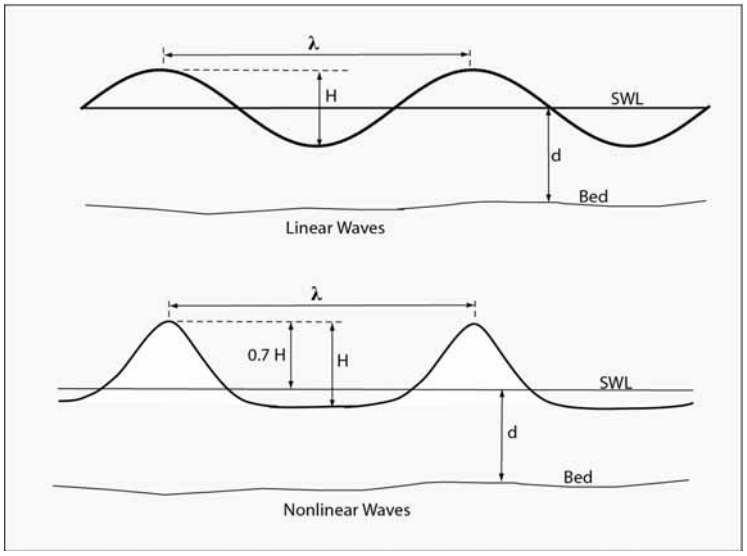
Biloxi, MS

Biloxi, MS

Wind Generated Waves

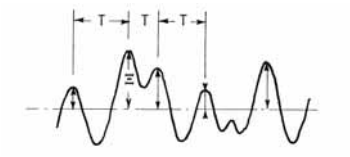
- Definitions:
  - Wave Height – Distance from trough to crest
  - Significant Wave Height – Average height of 1/3 highest waves
  - Wave Period – Time required for one wave to pass a fixed point
  - Peak Period – Period of waves with most energy

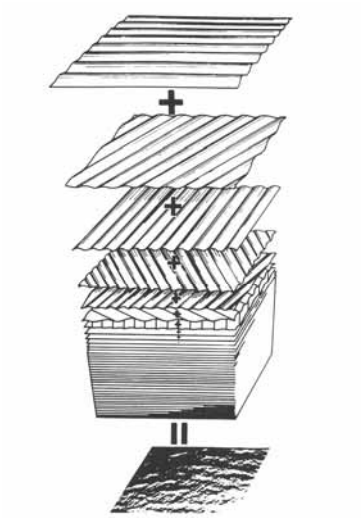
Wind Generated Waves



Wind Generated Waves

Hurricane Wave Field Composed of Waves with Range of Heights and Periods





Structure of random sea (Pierson *et al.*, 1958).

Wind Waves

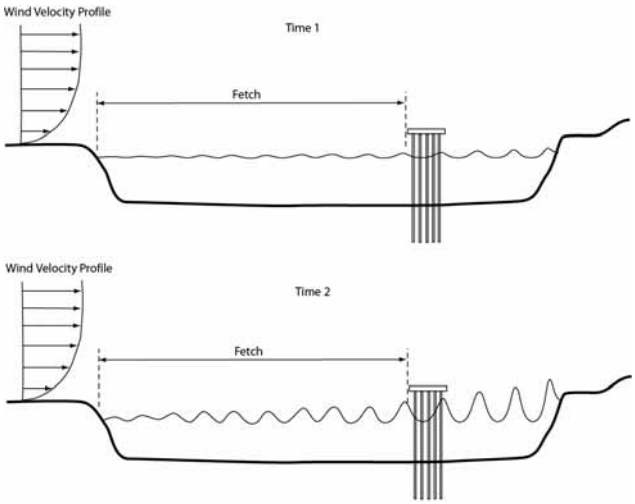
Height and Period (Length) Depend on:

- Wind Speed
- Wind Duration
- Fetch Length
- Water Depth

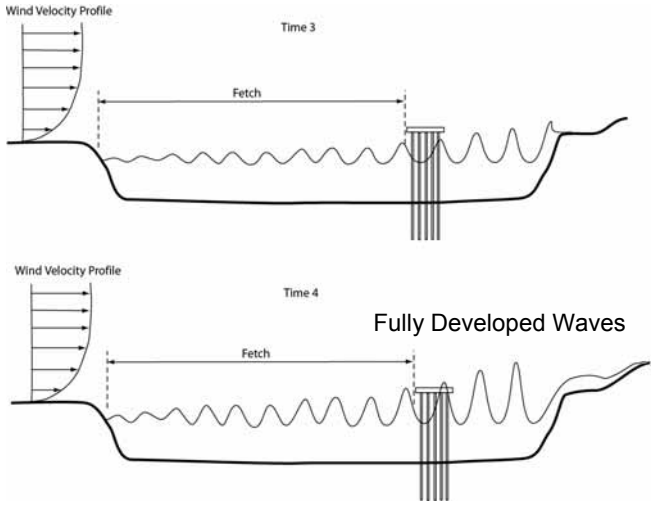
Wave Height Limitations

- Water Depth: $H_{max} < \sim 0.8 \times \text{Depth}$
- Wave Steepness:
  - Deep water
    - $H_{max} < \sim 0.14 \times L_0$
  - Shallow water
    - $H_{max} < \sim 0.082 \times L_0$

Fetch Length – Wind Duration

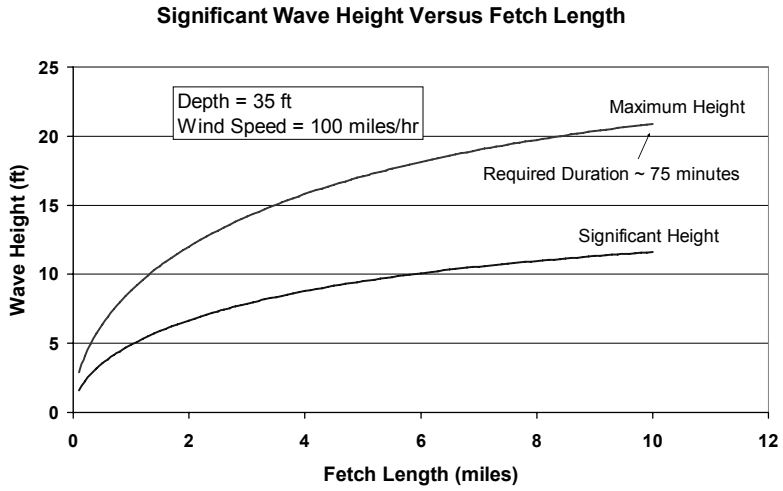


Fetch Length – Wind Duration



Fully Developed Waves

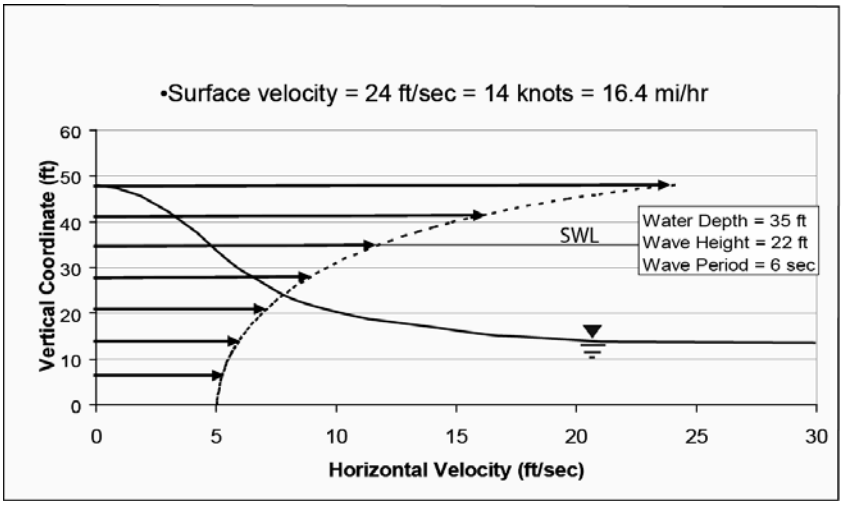
Influence of Fetch Length



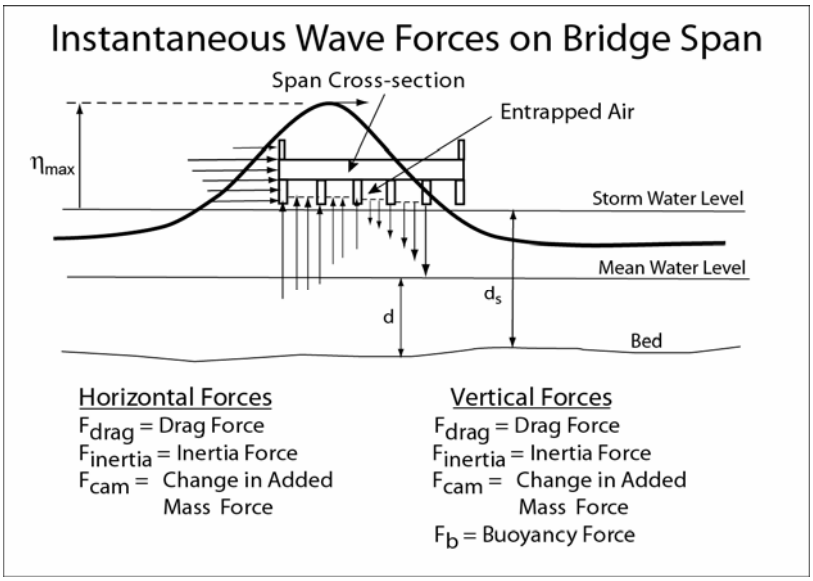
Storm Surge/Wave Forces

- Storm Surge/Wave Forces depend on:
  - Storm surge elevation
  - Wave heights and periods
    - Water particle velocity
    - Water particle acceleration
  - Structure shape, dimensions, and elevation relative to the storm surge water level

Horizontal Velocity Profile Under A Wave Crest - Example



Surge/Wave Forces



Wave Force Research

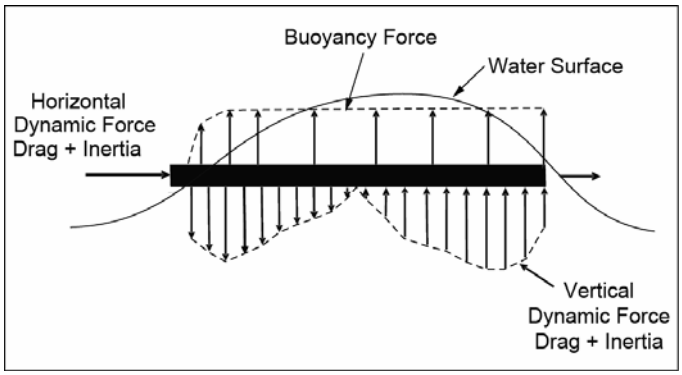
- Research Objective
  - Improve ability to accurately predict surge/wave loading on bridges
- Approach
  - Improve and extend existing theory to include bridge span structures
  - Conduct wave tank tests with instrumented model bridge spans
  - Use field data from Hurricanes Ivan and Katrina to test/verify predictive equations

Wave Force Research

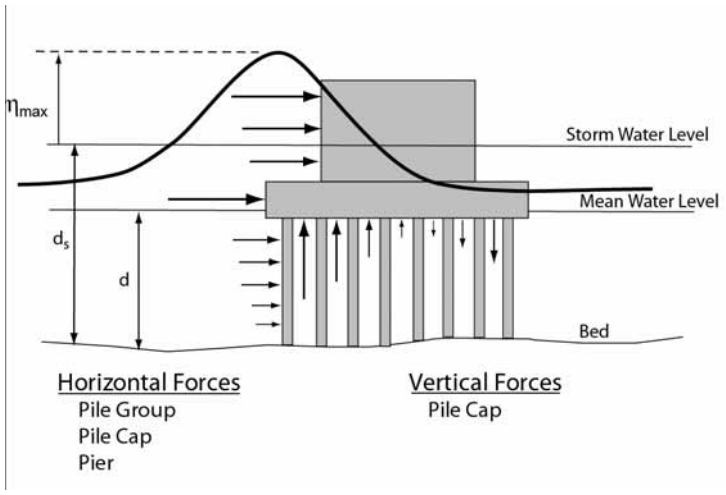
- Theoretical
  - Extending theory to include surge/wave forces on bridge spans

Wave Force Research

- Theoretical
  - Moments as well as forces essential to computing structural response



Wave Force Research

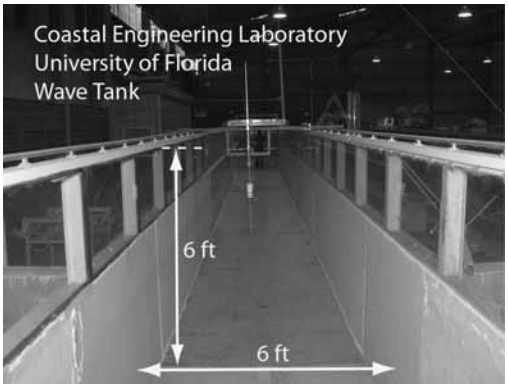


Wave Tank Tests

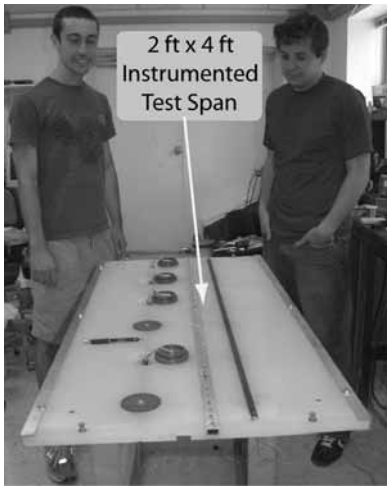
- Sufficient measurements to identify components of horizontal and vertical forces
- Instrumentation
  - Four three-component load cells
  - Pressure transducers on top and bottom
  - Wet/dry sensors on top and bottom

Wave Tank Tests

- Wave Tank
  - 6 ft wide x 6 ft deep x 120 ft length
  - Random wave generator



Test Setup



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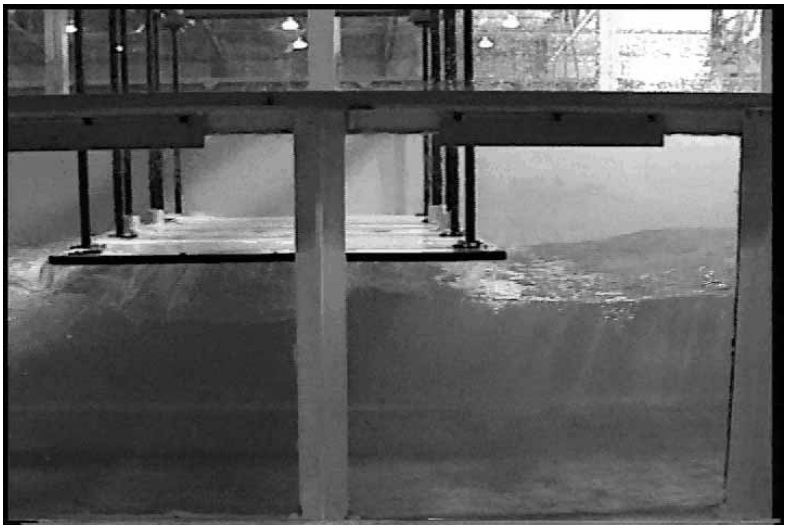

Summary

- Surge/wave Forces Depend on:
  - Surge height
  - Wave height and period
  - Structure shape and size
  - Structure elevation relative to surge elevation
- Wave Height and Period Depend on:
  - Wind speed
  - Wind duration
  - Fetch length
  - Water depth

Summary

- Research Objectives:
  - Improve existing theory and extend to include bridge span structures
  - Perform wave tank tests with sufficient instrumentation to distinguish between different components of wave induced forces and moments
  - Use laboratory and field data to test/verify theory

Questions, Comments

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