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Wave loads on exposed piers / jetties – including "what went wrong at Blankenburge?"

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Contents

- Wave loads on decks
  - pulsating and impulsive loads
  - Examples coastal structures
  - Research tests
- Results and guidance
- Failures of US highway bridges
- Blankenburge pier
  - Physical model study
  - 3-d effects and impulsive wave loads
  - Mitigation measures
- Conclusions

Waves on vertical walls

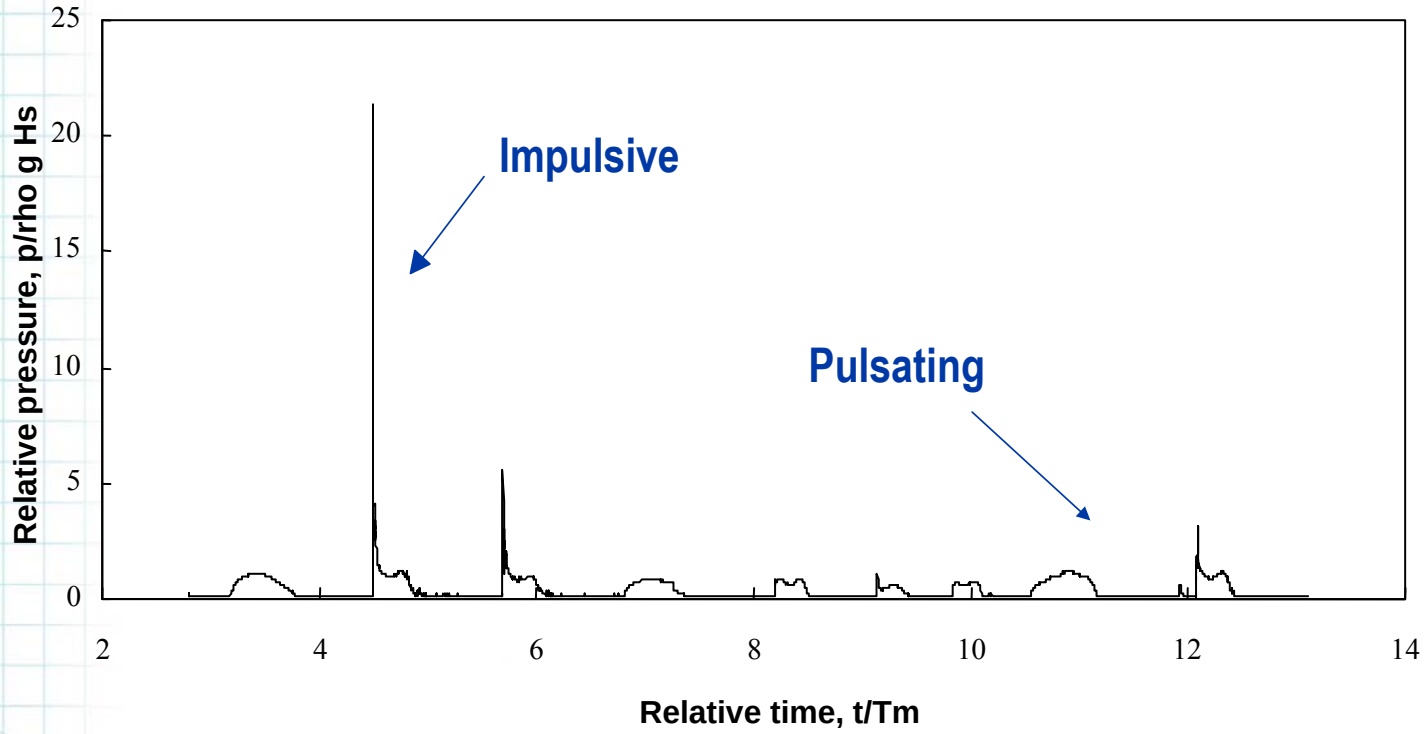
Impulsive wave breaking against vertical walls

⇒ high overtopping

+ high velocities

+ intense local pressures

Wave forces on vertical walls



Wave loads on vertical, battered or composite walls, model test data from Allsop et al (1996), McKenna (1997)

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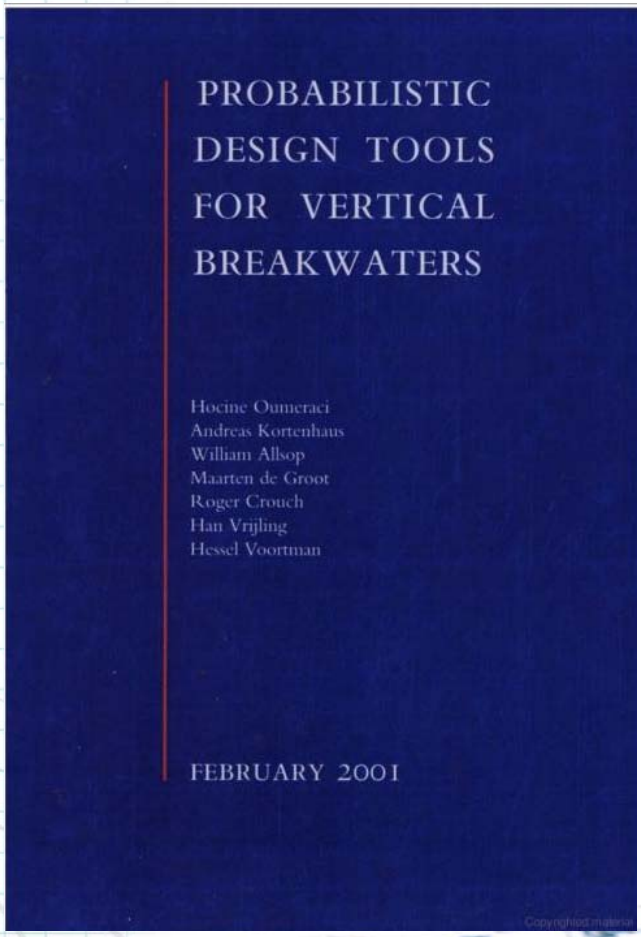
Wave forces – technical guidance



Results of EC research project PROVERBS, including guidance on wave forces on vertical breakwaters and seawalls.

Wave forces on jetties / piers

Design intention: no wave forces on jetty / pier deck.

Piled jetties / piers for loading / unloading oil or gas, cement or other bulk materials

Wave forces on jetties / piers

Photos courtesy of Mario Tirindelli, Coastal & Harbour Engineering

Hurricane Wilma, Cozumel Island (Mexico) October 2005

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Wave forces on jetties / piers

Photo courtesy Han Padron

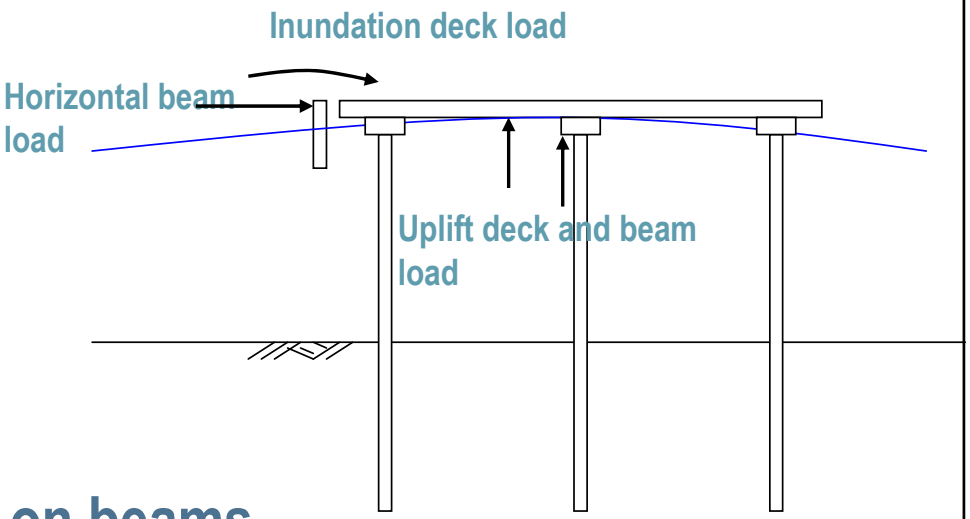
Damage from wave forces, driven by waves shoaling and reflecting under deck

Wave forces on jetties / piers

Photo courtesy Seacore

Wave forces on jack-up platform

Wave forces on jetties / piers



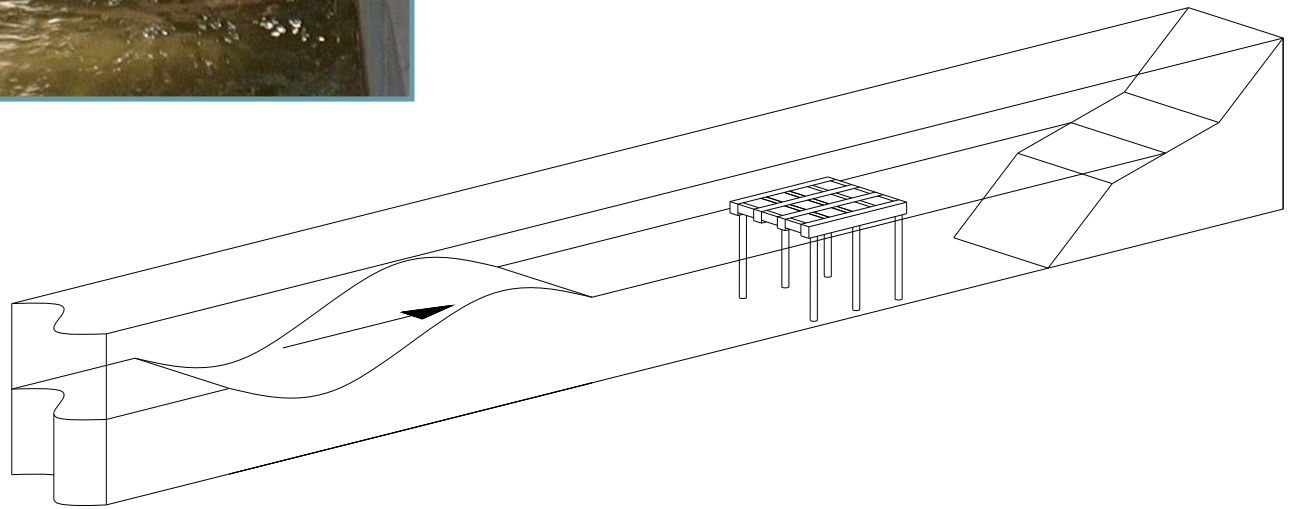
Wave load types

- No load, air gap
- Horizontal loads on beams
- Uplift loads on beams
- Uplift loads on decks
- Downward loads on decks (inundation)

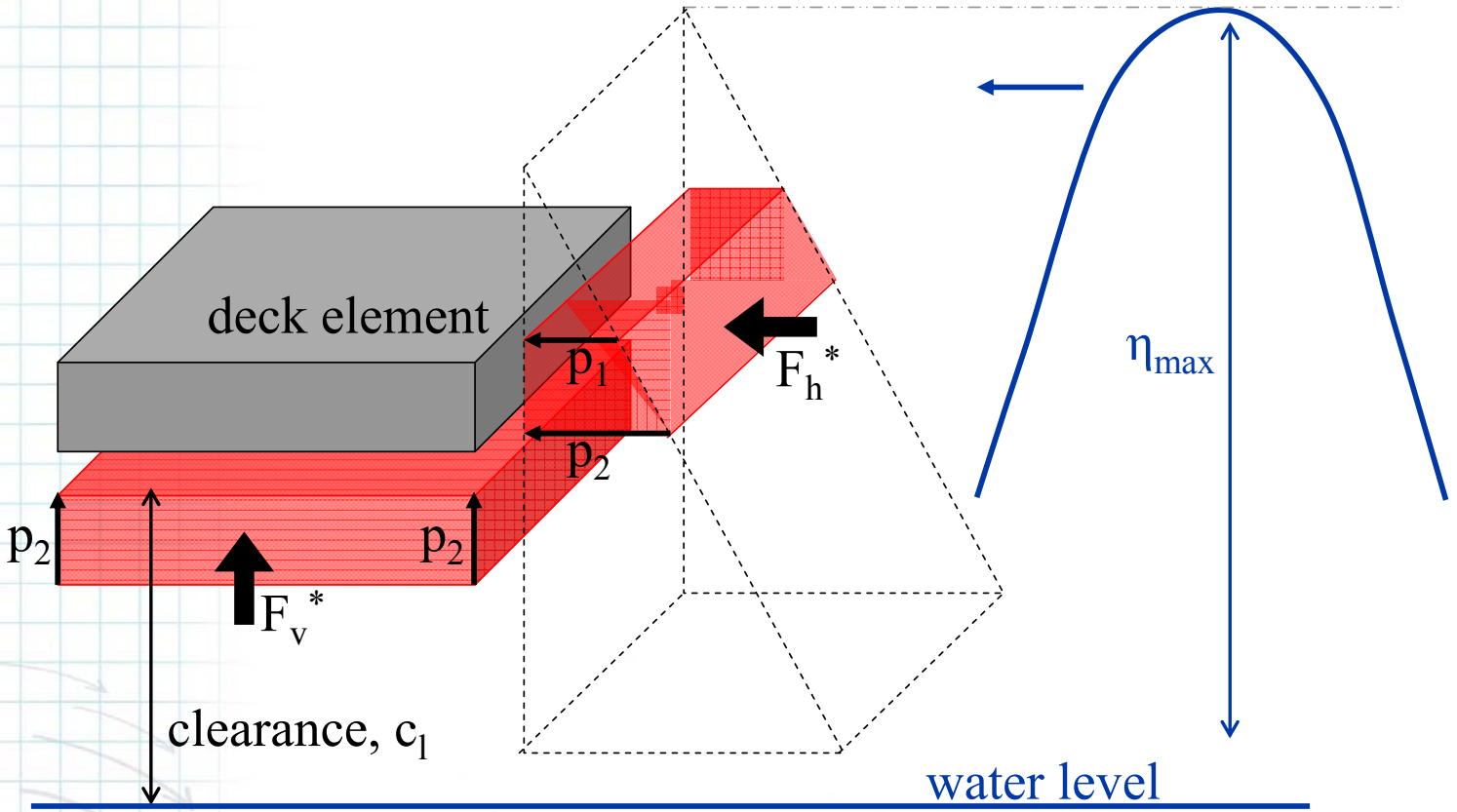
Wave forces on jetties - test design

- Test structure based on typical jetty head
- Measurements on 2 x deck

  + 2 x beam

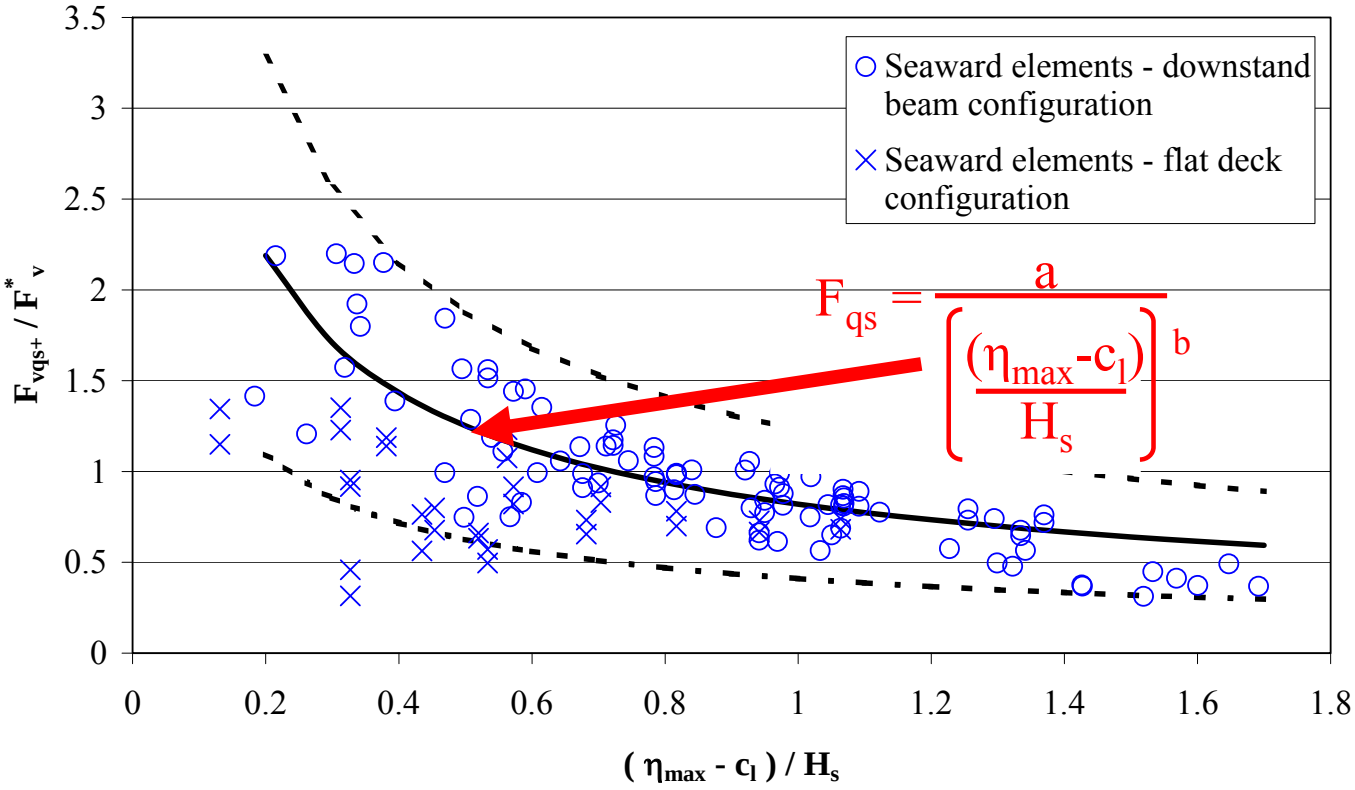


Wave loads on jetties

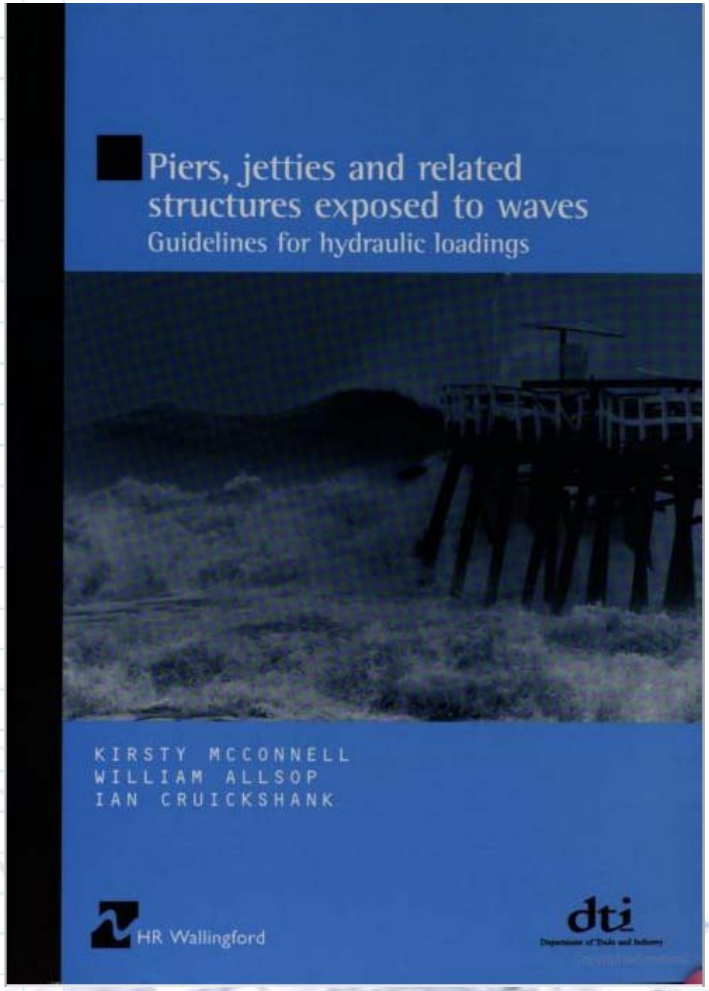


Definition of "basic" wave forces F_h^* and F_v^*.

Wave loads on jetties



Wave forces – technical guidance



Results of UK research project on "Exposed Jetties", including guidance on wave forces on decks / beams – published by ICE, Thomas Telford.

Job done?

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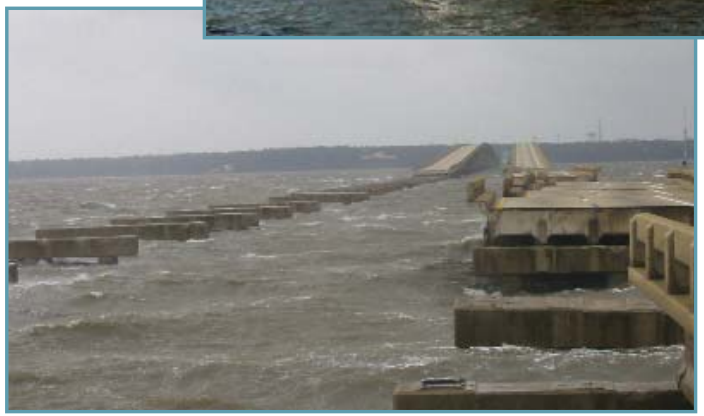
Wave loads on jetties



Damage during Hurricanes Katrina & Ivan – images from Federal Highway Administration Wave Force Workshop, Dec 2005

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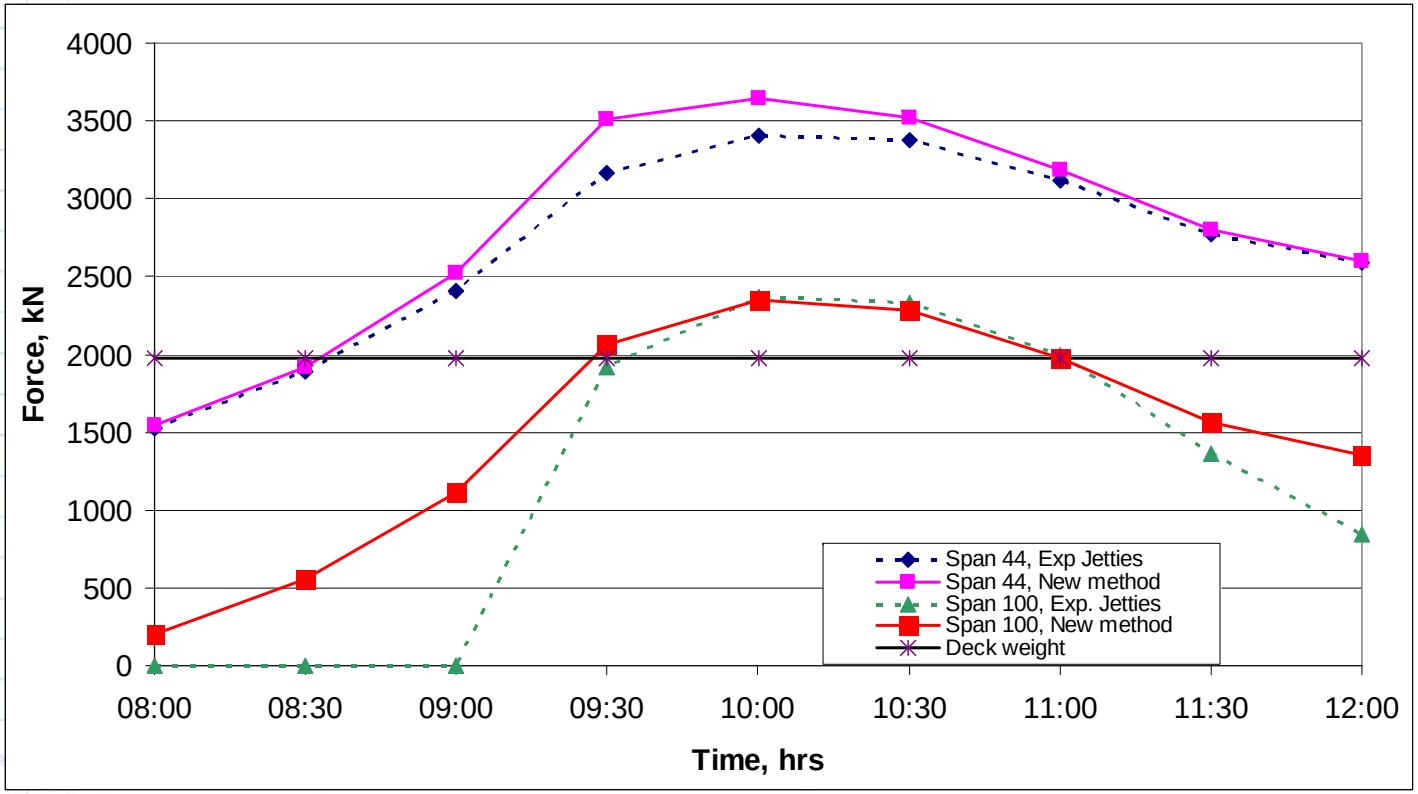
Wave loads on jetties



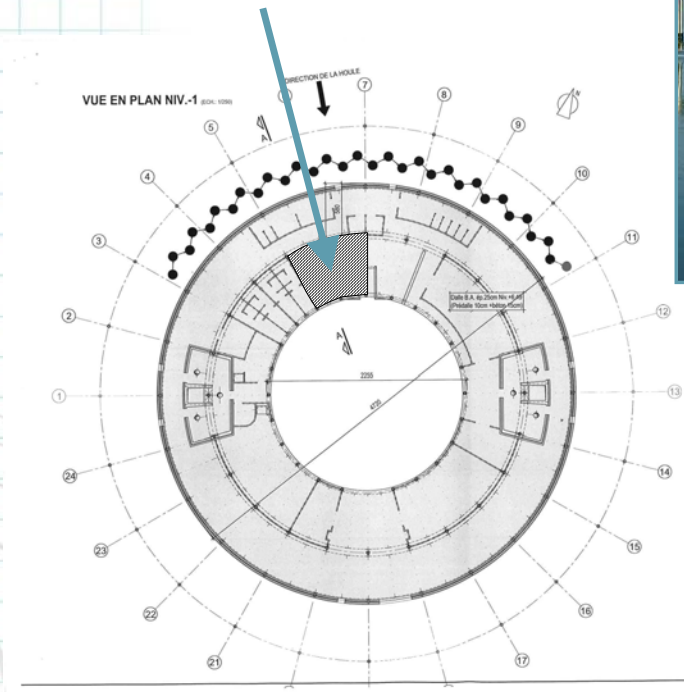
Application of analysis method - Uplift forces on I90 bridge deck, quasi-static loads

Blankenburge pier case study

Loaded element:

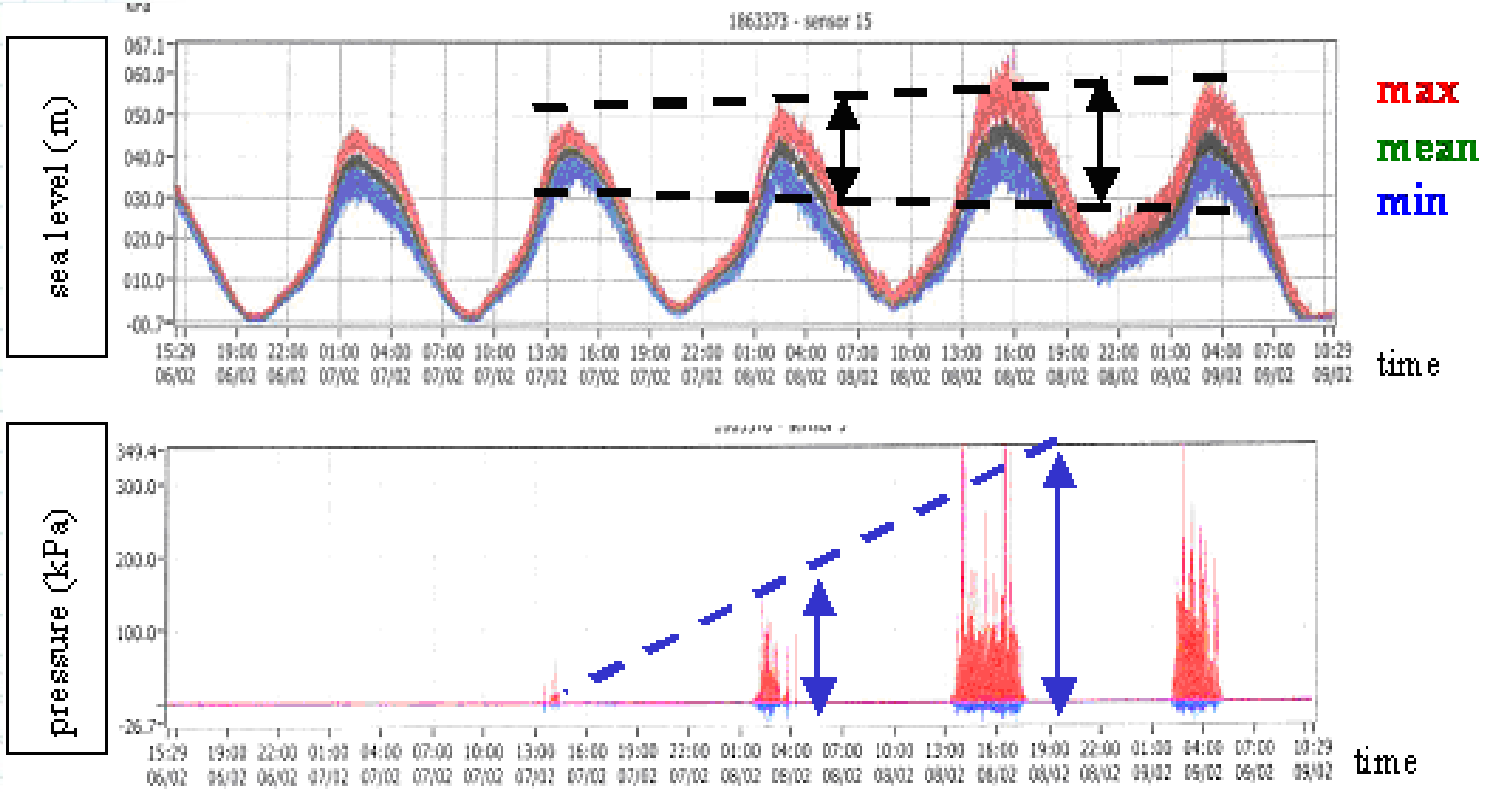
Mass of slab = 10.7 t

stiffness = 2.8 x10^8 N/m

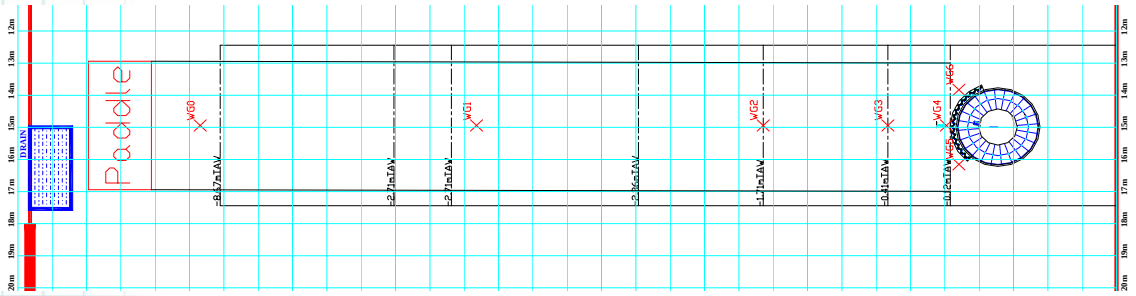


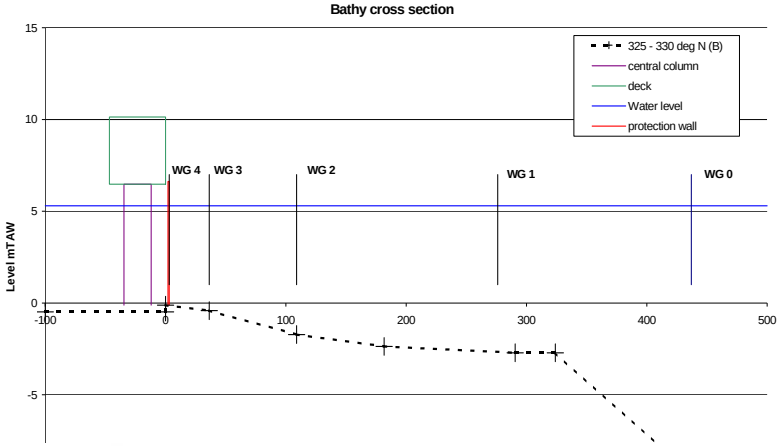
Field measurements give impact pressures of p≈500kPa for H_s = 2.8 - 3.2m

Field measurements



Physical modelling





Model scale : 1:20

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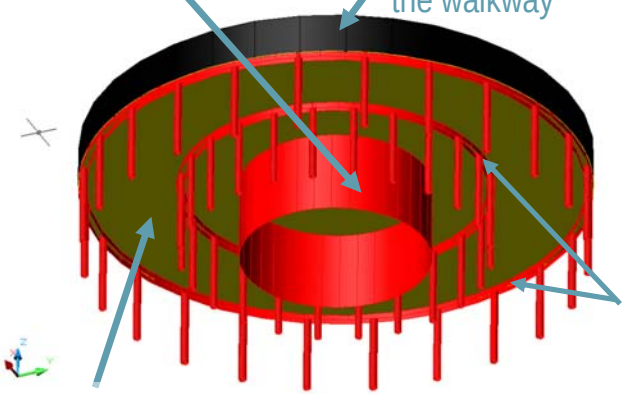
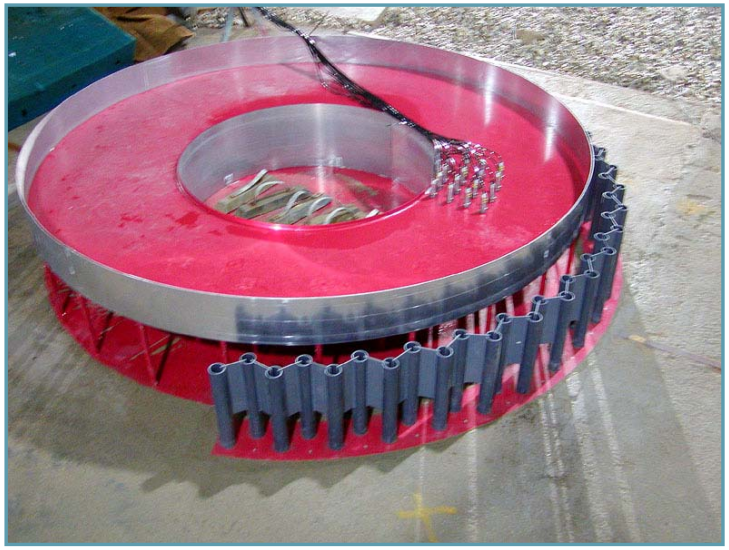
Physical modelling

Tests run for 1000 waves, to give results at appropriate statistical exceedance level.



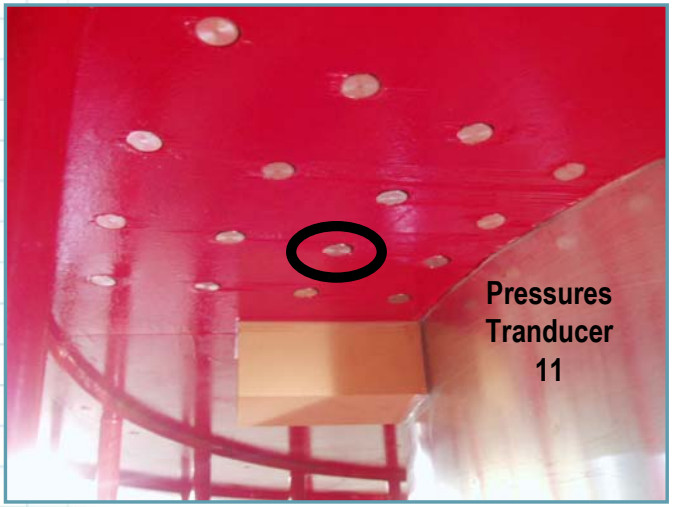
Protection wall

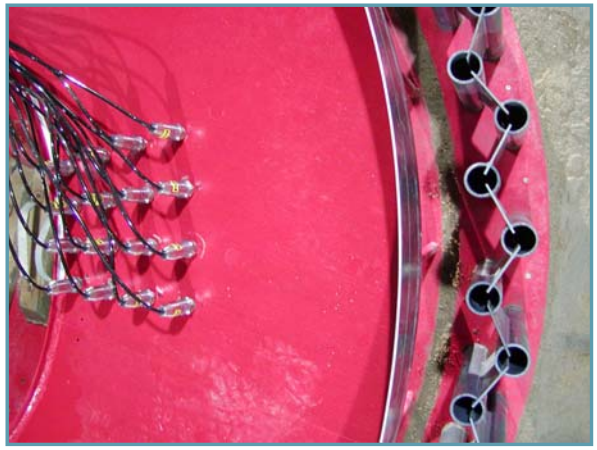
Without Protection Wall



With Protection Wall

Measurement of pressure

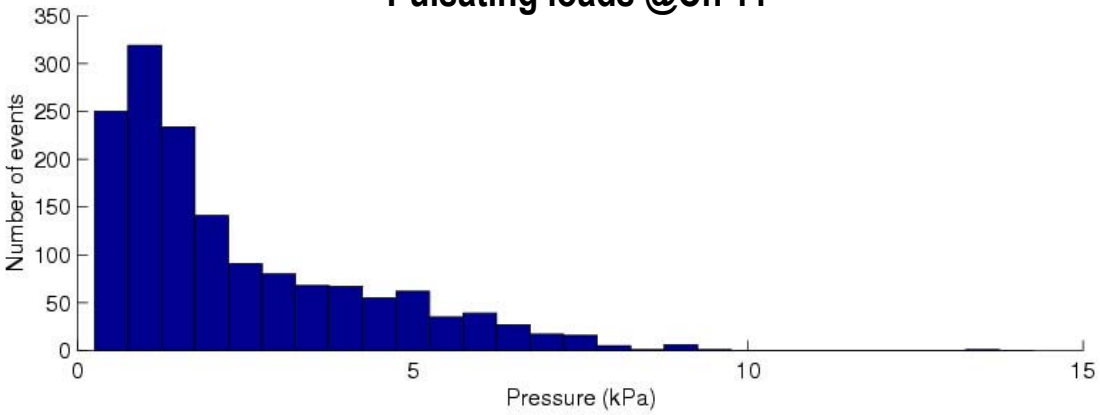




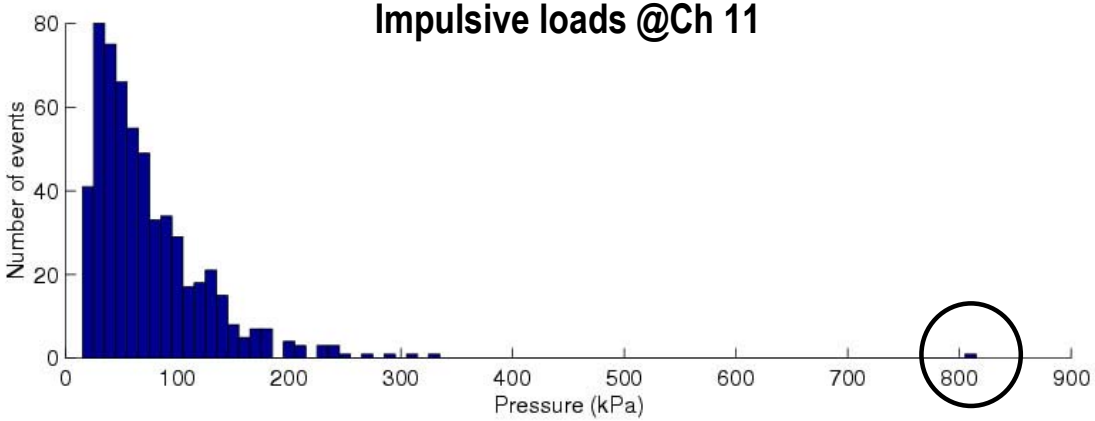
Pressures were logged at
10,000Hz for 20 – 40 mins

Pressure results

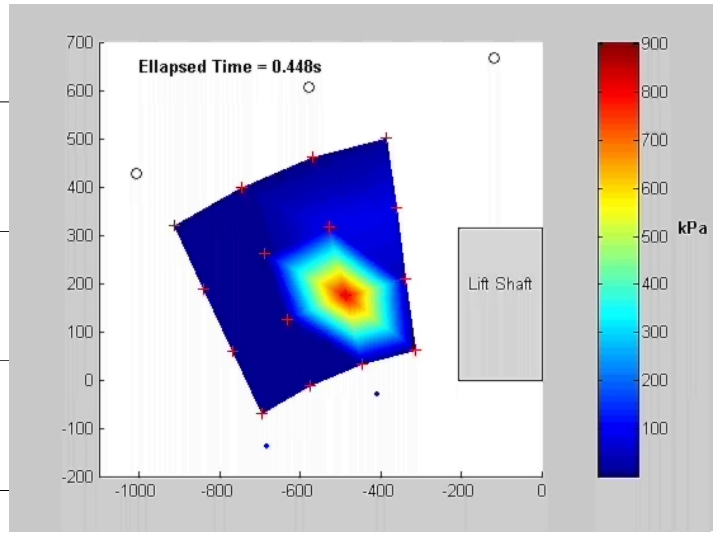
Pulsating loads @Ch 11



Impulsive loads @Ch 11



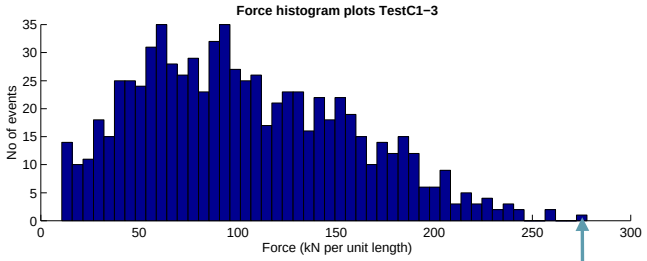
Impulsive pressure

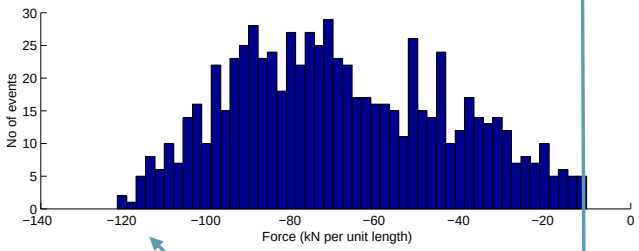


Wave loads on protection wall

Protection wall results

Horizontal Force - Return wall mounted on 16% porosity lower section

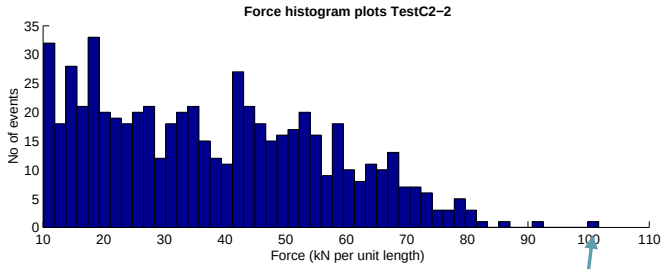


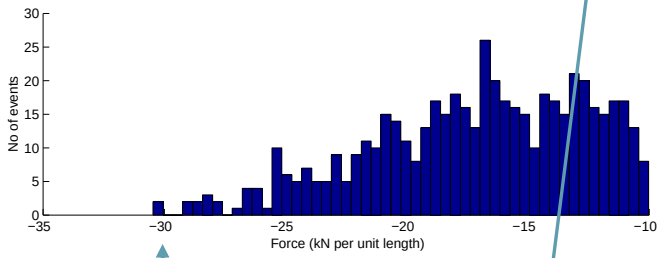


Max Fh = 275 kN / m

Min Fh = -120 kN / m

Horizontal Force - 16% porosity lower section





Max Fh = 100 kN / m

Min Fh = -30 kN / m

But …..informal observations in 2007!

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Conclusions

- Impulsive loads on vertical / battered etc walls can be predicted, but were often not understood, and data on durations are uncertain.
- Pulsating loads on decks can be quantified for most (simple) conditions. Predictions for local / impulsive loads are still over-simple.
- Understanding wave processes is essential in developing analysis and hazard assessment tools.
- Sod's law still works!

Research results from "Exposed Jetties" available from:
http://www.hrwallingford.co.uk/projects/JETTY/#top

Fourth International Forensic Engineering Conference, ICE, Dec 2008.