Water Research Laboratory | School of Civil & Environmental Engineering

Floating Breakwaters as Public Platforms – Impact on Postural Stability

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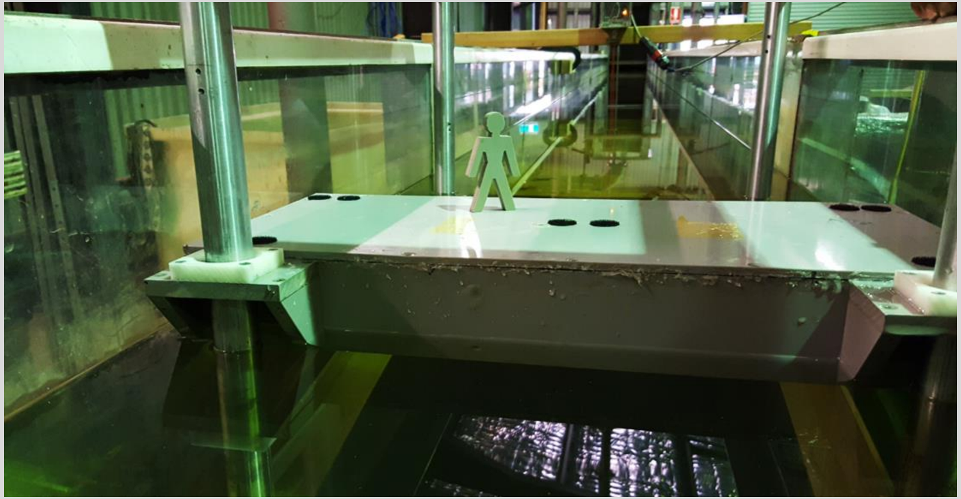
ACKNOWLEDGMENTS



Presented work is part of the PhD on

Dynamic Motions of Floating Pontoons and Associated Postural Instability

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THE PROBLEM

- Floating breakwaters move as a result of wave actions – ***Dynamic Motions***

- For a person standing on a floating breakwater, these dynamic motions can cause ***Postural Instability***

- ***Dynamic motions*** and associated ***Postural Instability*** currently not covered in floating breakwater design codes/standards

FLOATING BREAKWATERS

- Floating structure that interacts with incident wave energy in upper part of water column leading to reduction in wave height on leeward side
- Suitable for short period waves (2 - 5s) design wave height under 1 metre
- Wave attenuation achieved through reflection, out of phase damping, interference with water particle motions and viscous damping
- Today discussing piled box pontoon breakwater

FLOATING BREAKWATER DESIGN

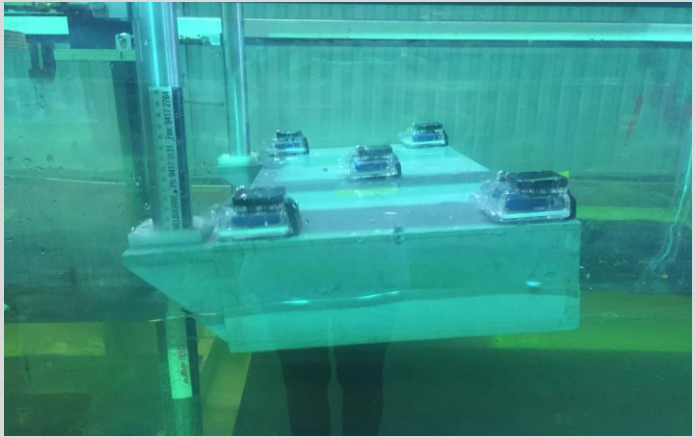
- Minimal design codes available
  - Establish appropriate design criteria – transmission coefficient $K_t = H_T / H_i$
  - Review existing test results for similar structures
  - Model testing
  - Select design based on performance criteria and cost

- **What about limits on motions if used for public access?**

FLOATING BREAKWATER MOTIONS

- Wave attenuation performance influenced by:
    - Structure - Width, draft and mass
    - Hull – Shape/perforations
    - Mooring system
    - Water depth
    - Wave period

- **How can attenuation be related to motions?**
- **What impact do these motions have on postural stability?**



HUMAN RESPONSE TO MOTION

Age
Size
Fitness
Expectation
Experience
Standing

PERSON

+

Magnitude
Frequency
Axis
Duration

MOTION

=

Postural
Stability

'Postural stability is the ability to maintain the body's centre of gravity over the base support during quiet standing and movement.'
(Hageman et al. 1995)

POSTURAL STABILITY - STANDARDS

- Some standards are available comparative to floating breakwaters including:
  - Vessels
  - Floating Bridges
  - Trains
  - Vibration effect

- No standards specific to motions of floating breakwaters and postural stability

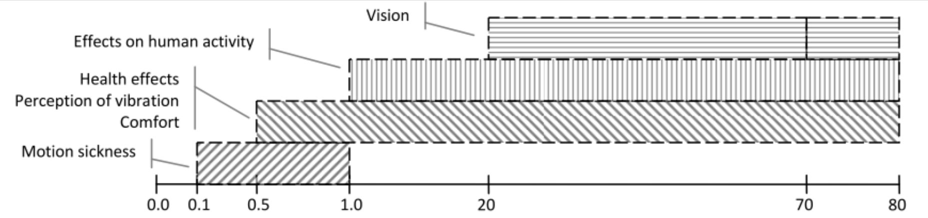
ABS Doc. No. 102: 2001
ABS Doc. No. 103: 2001
ASTM F1166-07
BS 6841:1987
BS 14253:2003
ISO 2631-1:1997
ISO 2631-4:1997
ISO 2631-5:1997
ISO 6954:2000
MIL-STD-1472F:1999
NATO STANAG 4154:2000
Graham (1990)

POSTURAL STABILITY – SAFE MOTION LIMIT CRITERIA

- Safe Motion Limit (SML) Summary

CRITERIA	LIMIT
Personnel Performance	1MII/min
Operation	
Vertical Acceleration (peak)	0.1 g
Lateral Acceleration (peak)	0.1 g
Comfort	
Vertical Acceleration (RMS)	0.02 g
Lateral Acceleration (RMS)	0.03 g
Peak angle of tilt	6°

- Frequency of acceleration
  - Lateral vibration stability issues - frequencies < 3.15Hz
  - Vertical vibration discomfort felt at all frequencies
  - Motion sickness 0.1 – 1Hz
  - Effects on human activity 1 – 80Hz



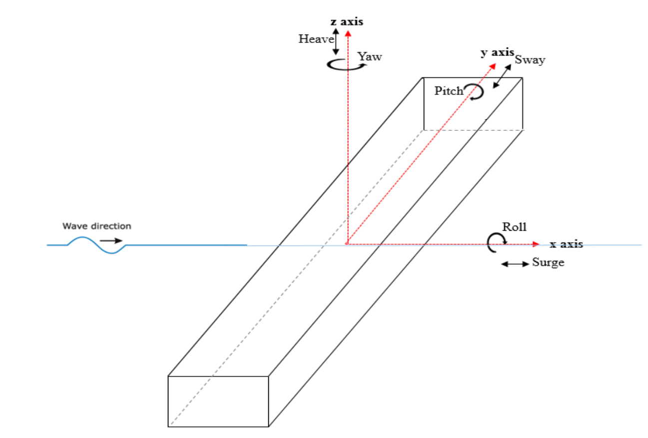
SOURCE: P.Matsangas 'Presentation - Human Performance Standards for Ship Motion Acknowledgments'

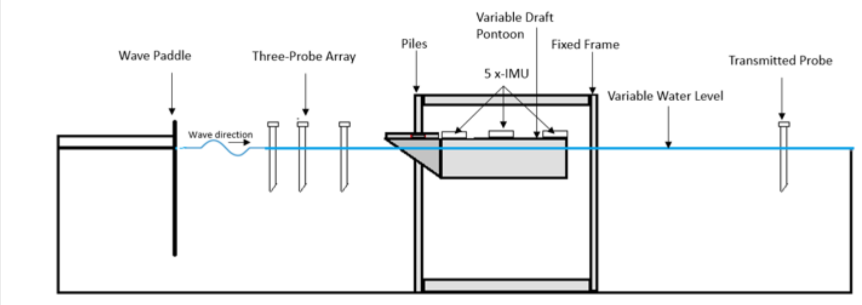
EXPERIMENTAL STUDY – 1.2m WIDE WAVE FLUME

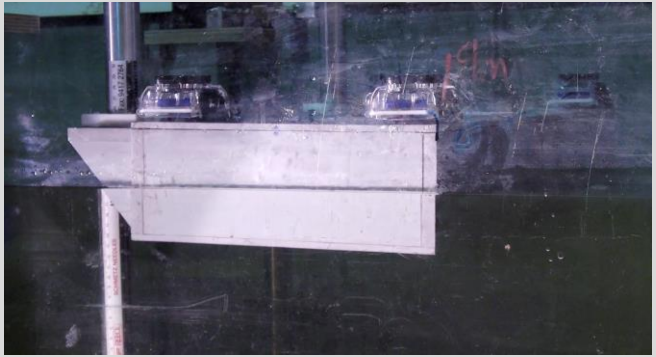
- Two model floating breakwaters differing width/beam – 2.83m and 5.63m prototype
- Wave periods 2 – 7s prototype
- Wave height 300mm prototype

(Wave periods and wave height: BOAT WAKE)

- Accelerations/angles recorded using 5 x Inertial Measurement Units (IMU) – triple axis
- Three probe array
- Scale – 1:10

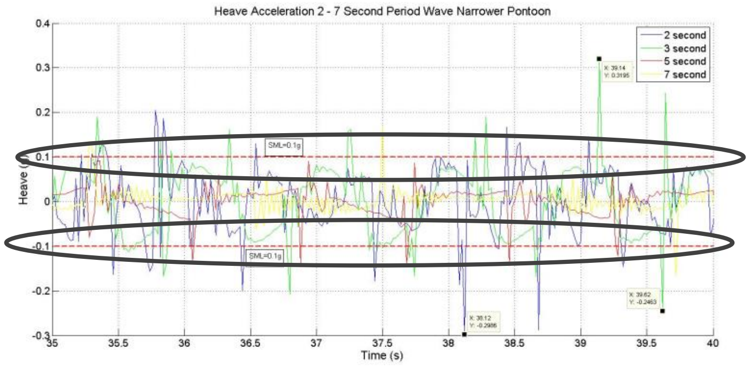


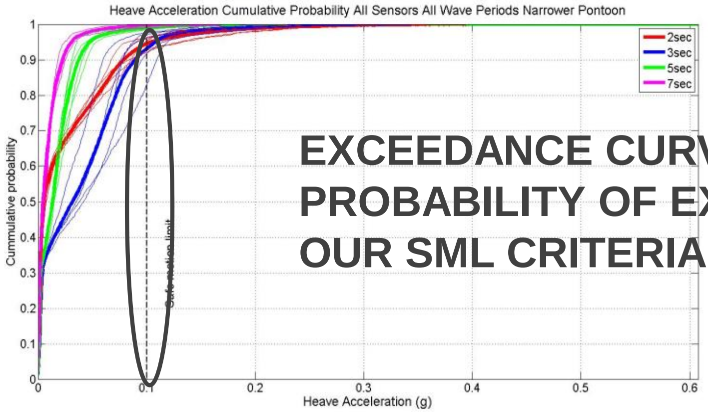




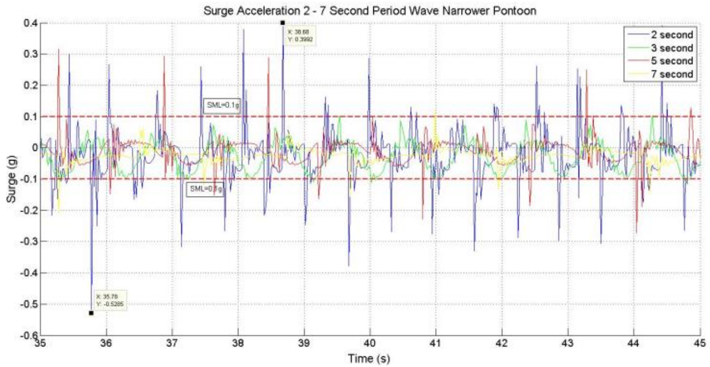
ACCELERATIONS – NARROWER BREAKWATER

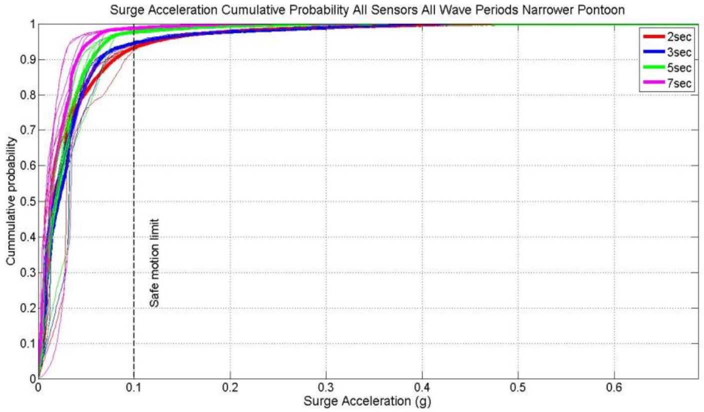
- Heave (z-axis) - Three second period wave highest probability of exceeding SML heave (8%)





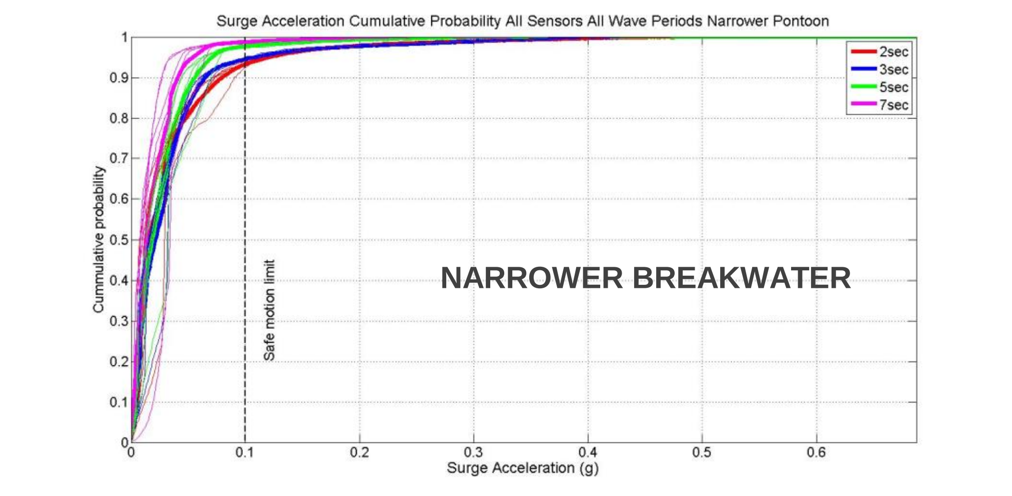
- Surge (x-axis) - Two second period wave highest probability of exceeding SML surge (7%)

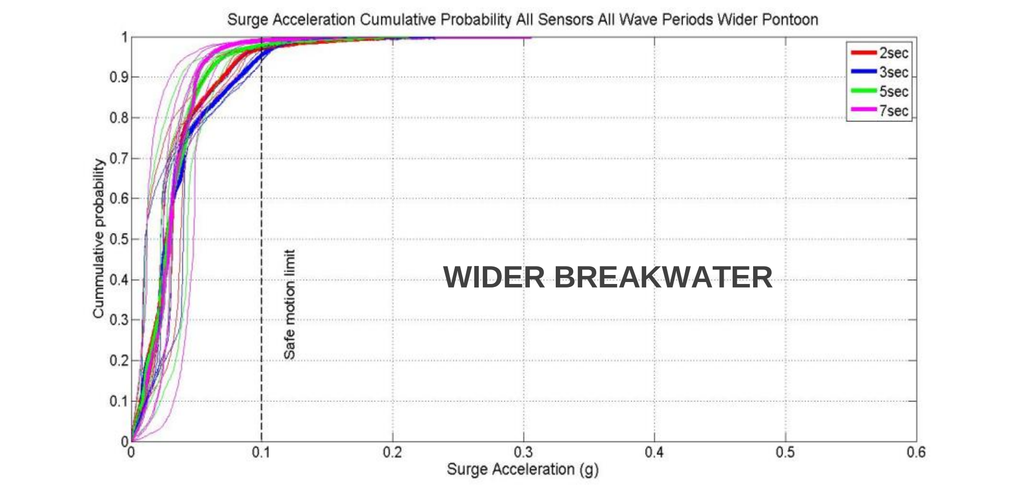




EXCEEDANCE CURVES – PROBABILITY OF EXCEEDING OUR SML CRITERIA

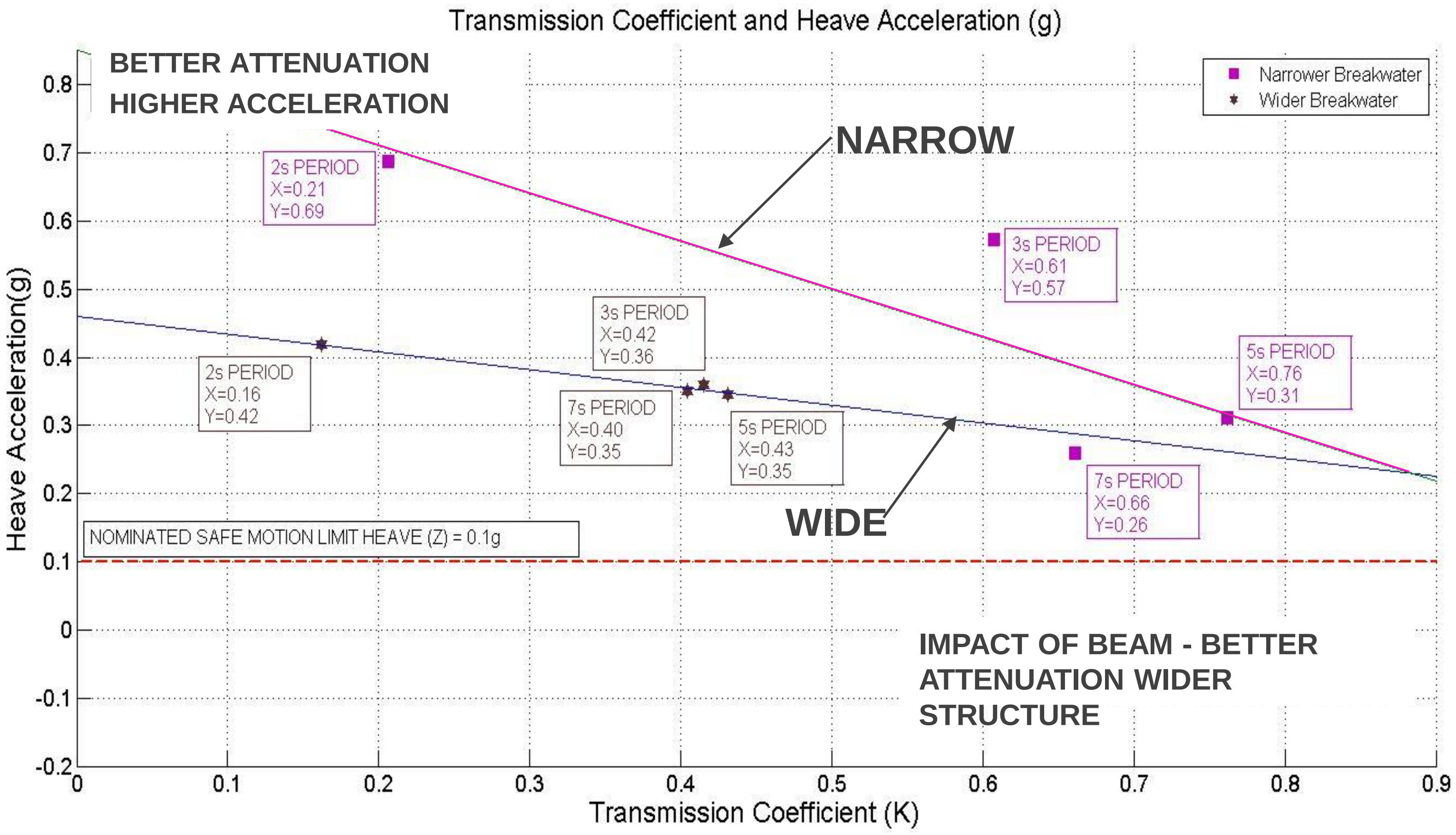
IMPACT OF BEAM - SURGE





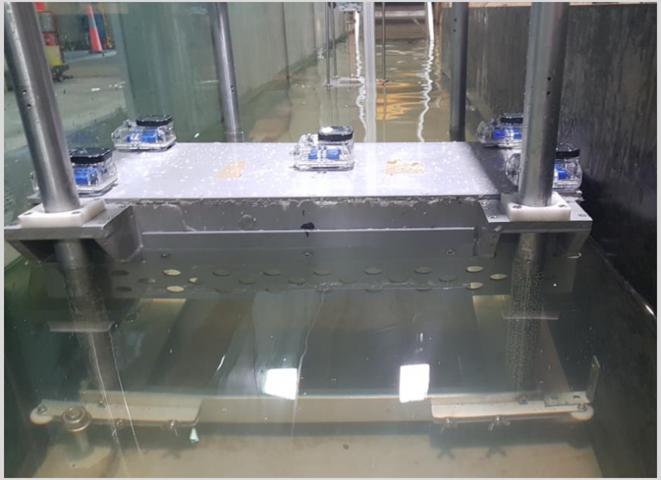
- **Results have shown that increasing beam → maximum magnitude of acceleration is reduced.**
- Wider breakwater behaves more adversely for longer wave period – relates to beam/wavelength (B/L) however magnitude of acceleration overall is reduced.
- **Wider breakwater overall lower probability of exceeding SML when compared with Narrower Breakwater in surge.**

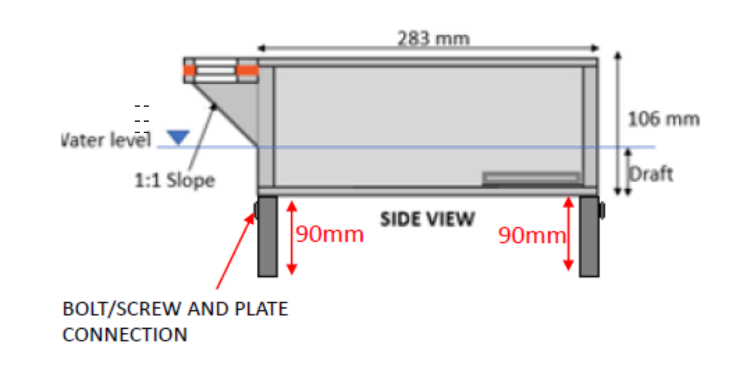
IMPACT OF INCREASED BEAM ON WAVE ATTENUATION

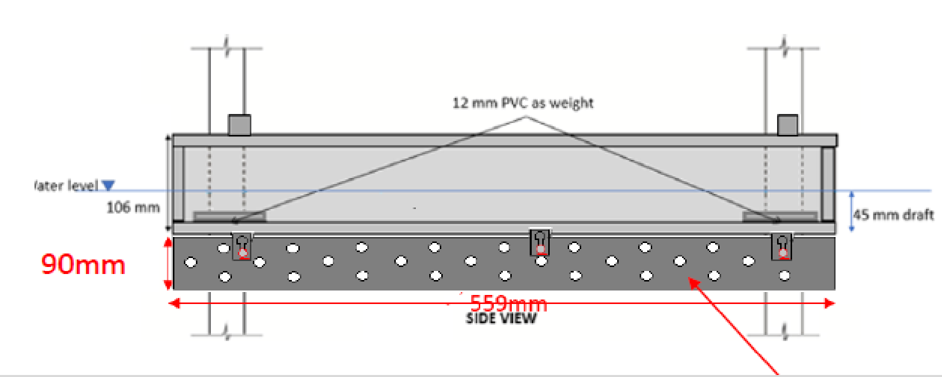


ALTERED DRAFT

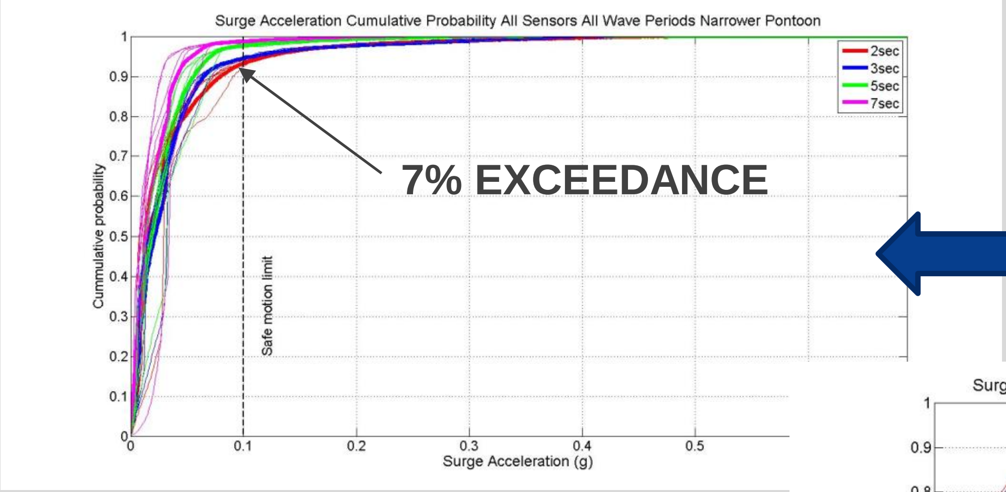
- Draft – 450mm to 715mm (prototype)
- Skirt testing – increased draft by 900mm prototype



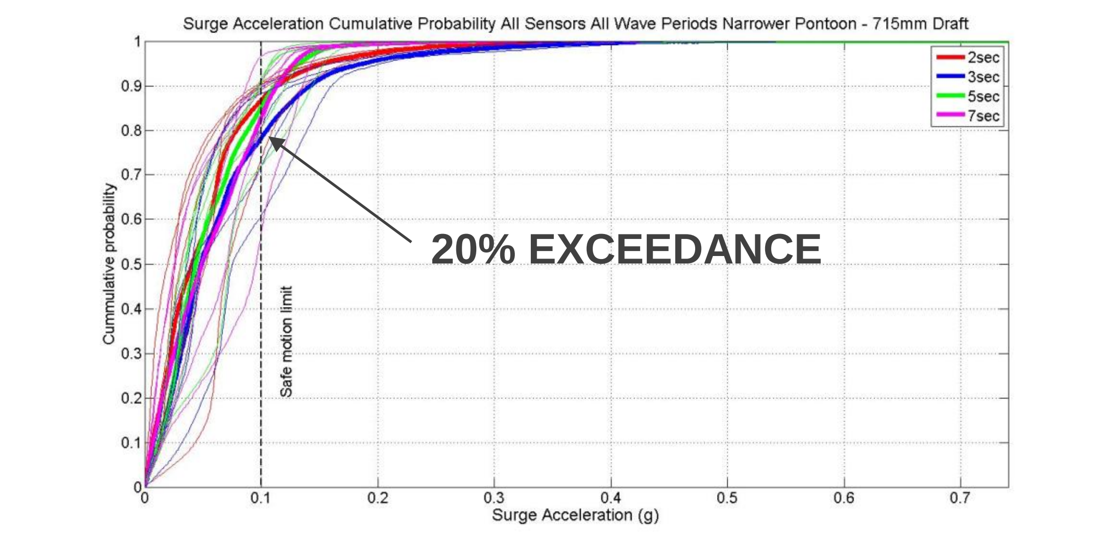




ALTERING DRAFT – NARROWER BREAKWATER



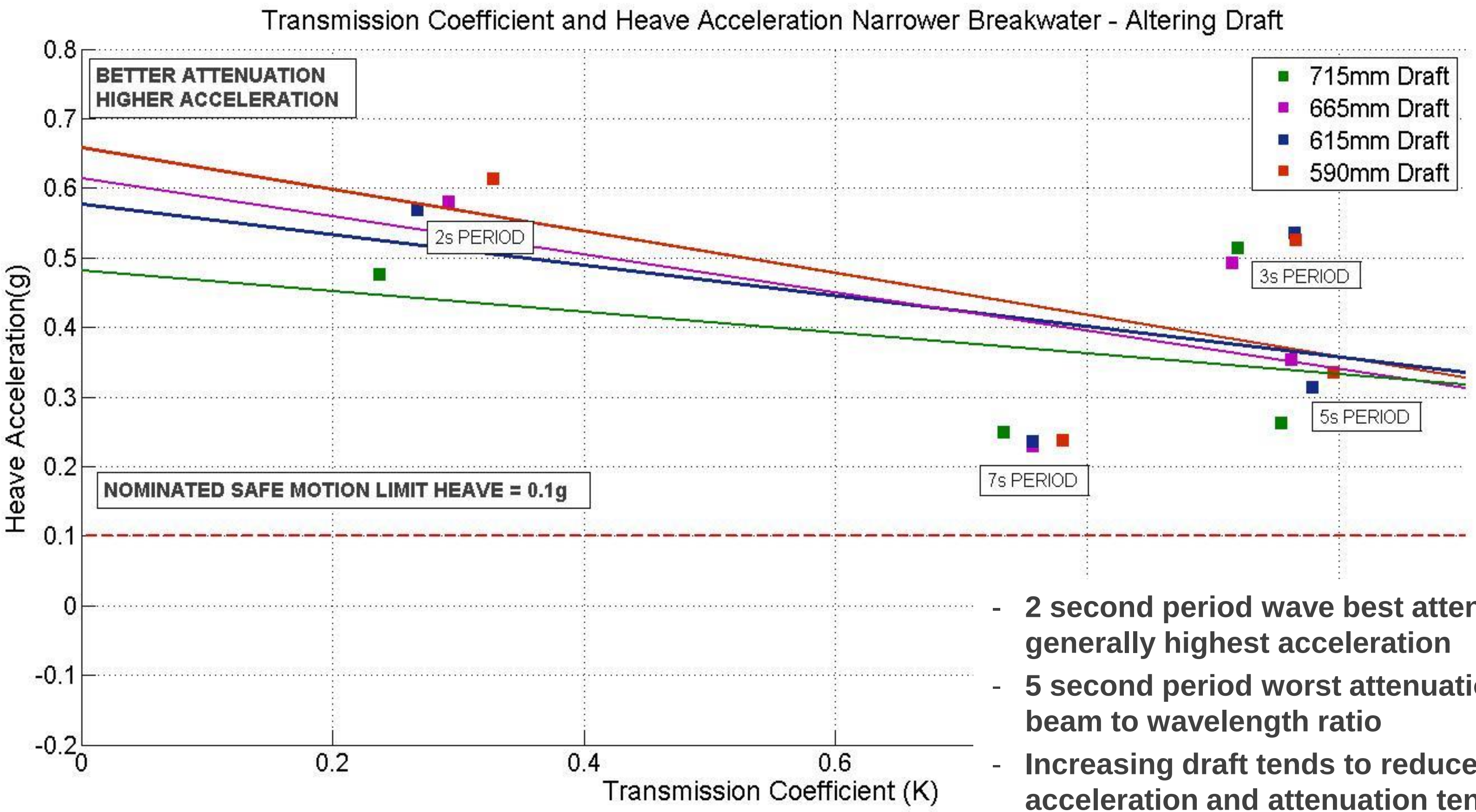
450mm DRAFT



715mm DRAFT

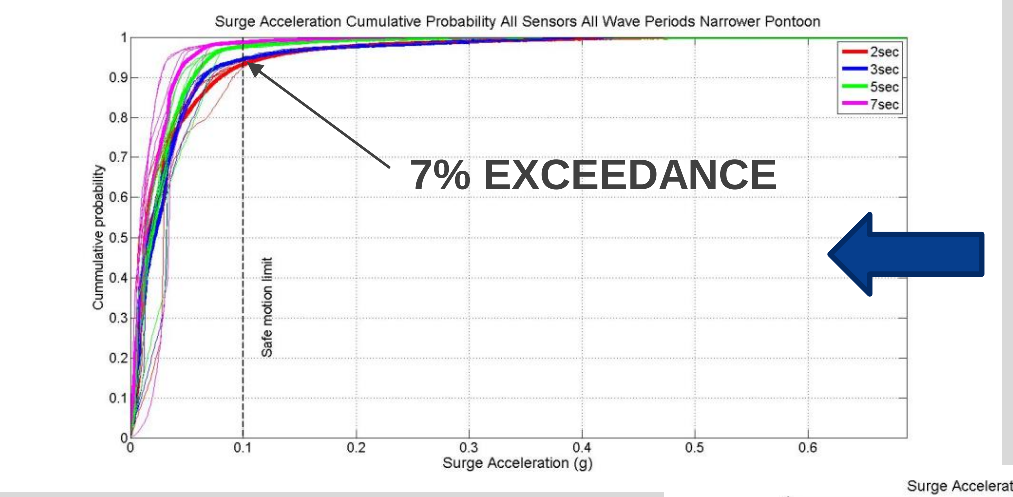
Higher percentage occurrence of accelerations exceeding SML however magnitude of acceleration reduced

ALTERING DRAFT – NARROWER BREAKWATER



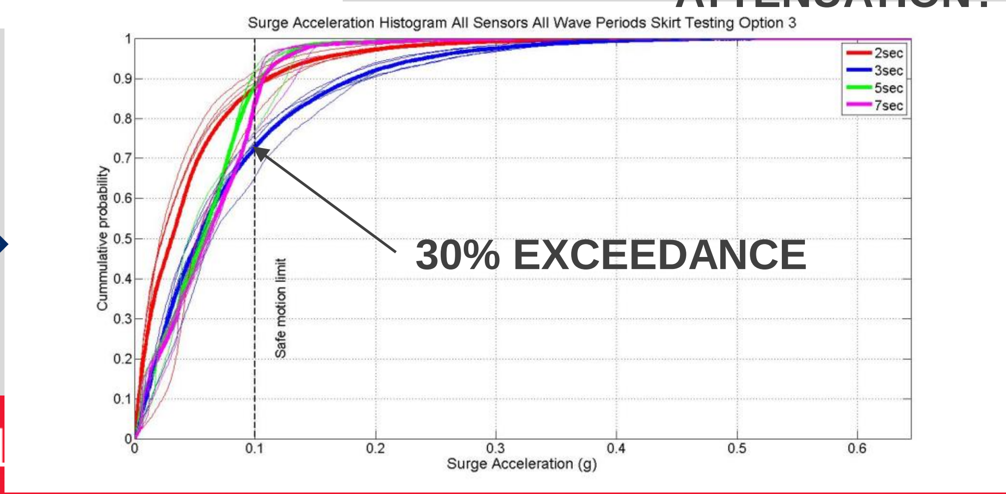
- **2 second period wave best attenuation generally highest acceleration**
- **5 second period worst attenuation – beam to wavelength ratio**
- **Increasing draft tends to reduce acceleration and attenuation tends to improve**

ADDING BREAKWATER SKIRT



NO SKIRT

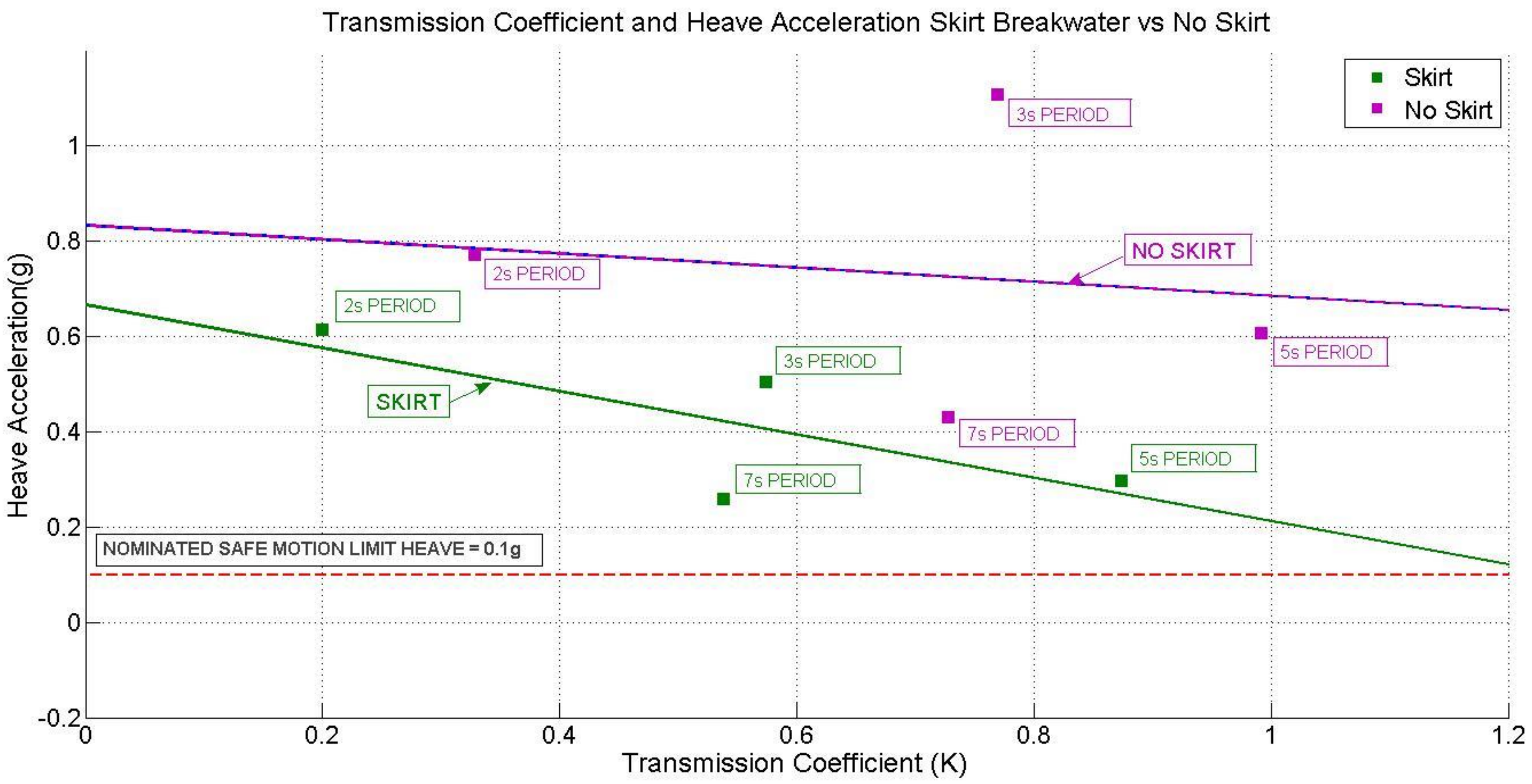
WHAT HAPPENS IN TERMS OF ATTENUATION?



SKIRT

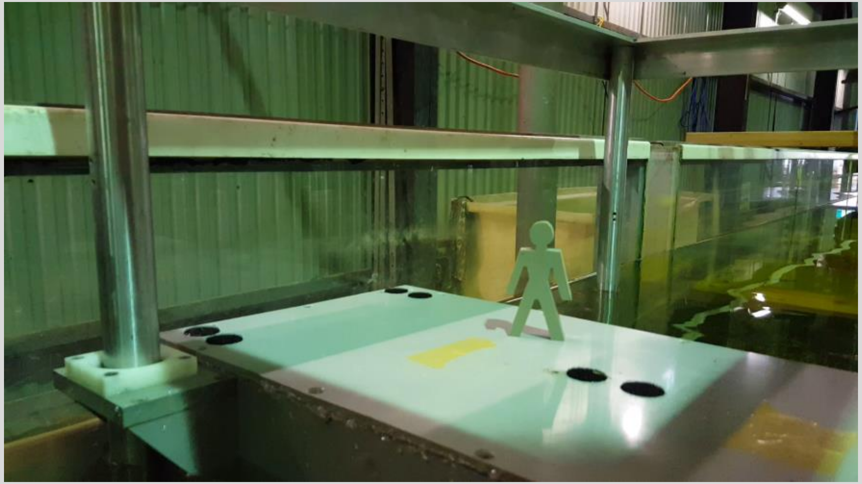
Higher percentage occurrence of accelerations exceeding SML

ADDING BREAKWATER SKIRT



RESULTS

- Best attenuation occurs when breakwater exhibits greatest level of dynamic motion
- Increasing beam improves wave attenuation performance and reduces dynamic motions
- Increasing draft improves wave attenuation and reduces peak accelerations however percentage exceedance of safe motion limit increased
- All tested scenarios exceeded nominated safe motion limits



CONCLUSION

- Currently designing to minimise wave heights – if breakwaters are multitasked need to consider dynamic motions

- Attenuation and dynamic motions can be improved by altering draft and beam

- Standards need to include motion limit criteria to be considered when designing floating structures