"UNDERSTANDING FLOATING WAVE ATTENUATORS"

BY:

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"UNDERSTANDING FLOATING WAVE ATTENUATORS"

COURSE DESCRIPTION

Currently, there are many "floating wave attenuator" products offered in the marketplace; however, very few provide the coastal engineering science to support their claims as attenuators and some are nothing more than robust versions of their standard floating dock products. This presentation will provide an overview of the wave attenuation basics, site suitability considerations, factors that affect the performance of floating wave attenuators, and recommendations for marina owners/operators considering floating wave attenuators for their facilities. Owners/operators will develop an understanding of the basic engineering science behind them and performance attenuation characteristics to ensure they get a true floating wave attenuator.

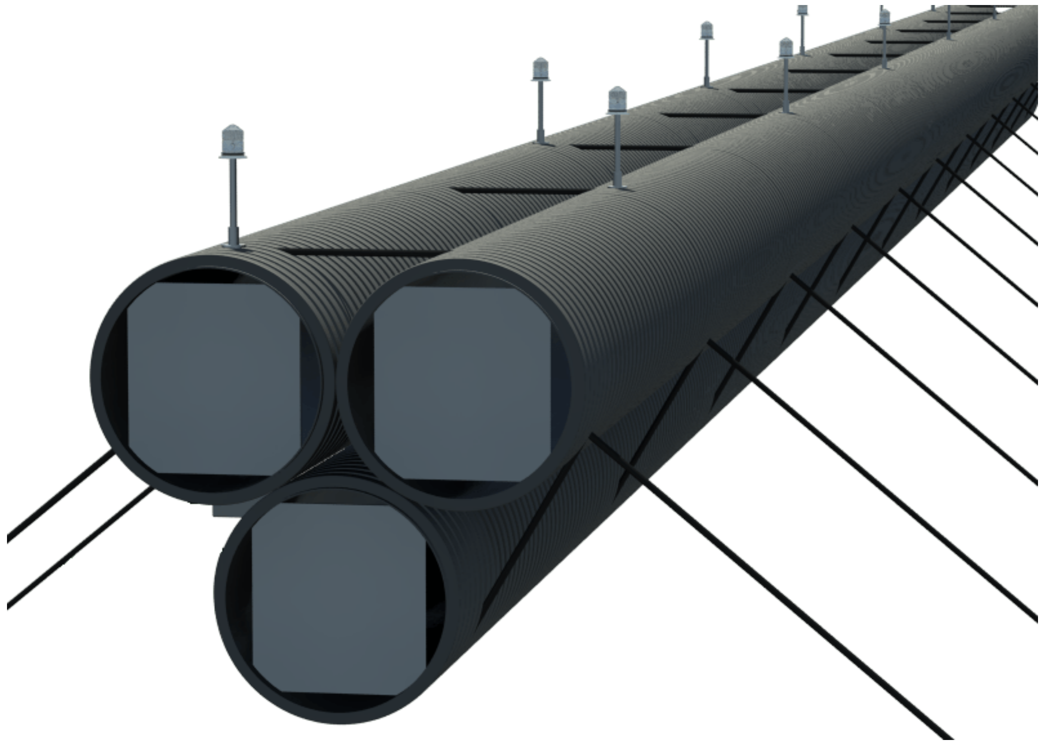
LEARNING OBJECTIVES

1. Overview of wave attenuation principles and engineering science
2. Overview of floating wave attenuators types
3. Site, performance and operational considerations for floating wave attenuators
4. Identify performance characteristics when selecting floating wave attenuators

“UNDERSTANDING FLOATING WAVE ATTENUATORS”

MOTIVATION

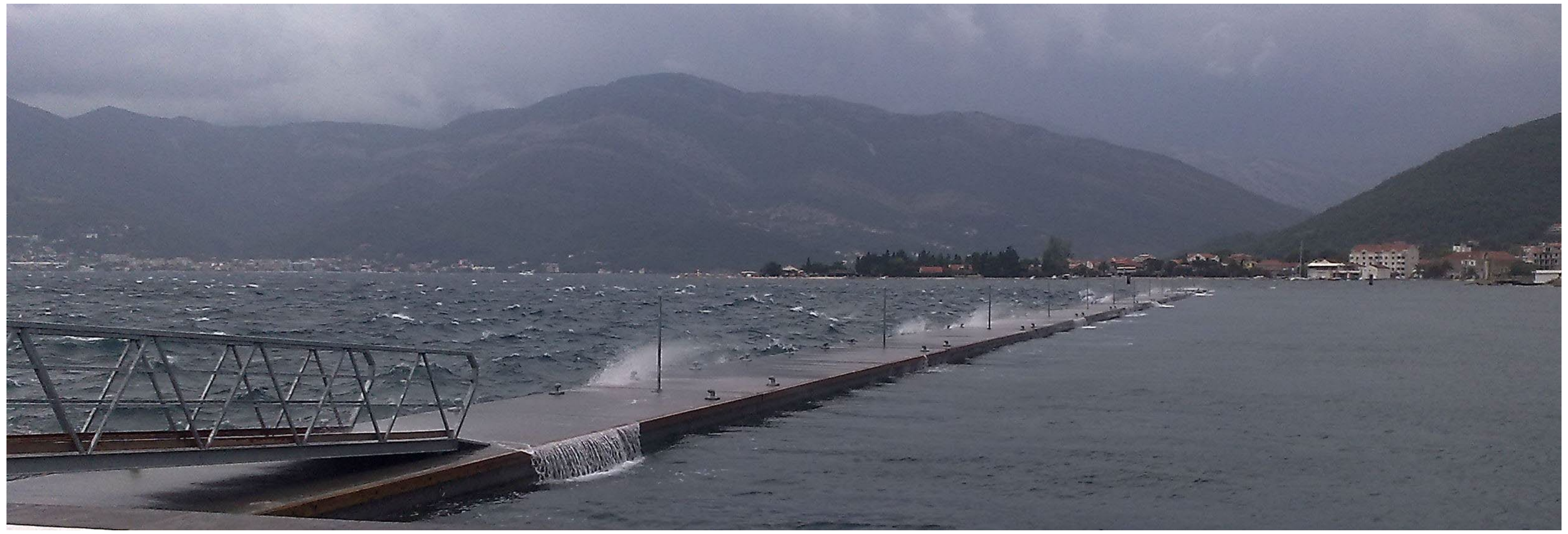
- “We don’t have any performance specifications for our floating wave attenuators. If it fails or doesn’t work, we just build it bigger next time”
  – US Dock Manufacturer
- Many (not all!) suppliers/manufacturers neglect the engineering science to support their floating wave attenuator products
- Climate change resulting in more frequent and more powerful storms placing many facilities inadequately protected
- Marina infrastructure becoming more recognized as engineered assets by local governments, engineering association and insurance companies
- Costly (in the long run) if not properly designed
- Risk to marina owners/operators



"UNDERSTANDING FLOATING WAVE ATTENUATORS"

WHAT IS A FLOATING WAVE ATTENUATOR

- Floating structure designed to greatly reduce wave energy from the exposed side to the protected side.
- Floating wave attenuators are installed to protect against specific conditions (e.g., wind waves and boat/ship wakes) to ensure more tranquil wave conditions.
- Site-specific <u>engineered</u> structures!



ARE THERE OTHER WAVE PROTECTION OPTIONS?

- Rubble/rock breakwater
- Wave screen
- Caissons
- Other

REASONS FOR FLOATING ATTENUATORS

- Deep water may prohibit practical fixed solution
- Soil conditions may be unsuitable for bearing structures
- Large water level fluctuations
- Less environmental impact
- Constrained plan area
- Cost
- Aesthetics
- Other considerations

"UNDERSTANDING FLOATING WAVE ATTENUATORS"

WHY DO WE NEED WAVE PROTECTION?

- Safe Mooring of Boats
  - Consider a 200 berth marina and average boat value is $100,000…that's $20million in assets!!)
- Maintain Functionality/Use of Marina and Harbor
  - Boat Ramp
  - Travelift & Dry Stack Forklifts
- Safe Navigation
- Maintain Structural Integrity of Docks/Marina Infrastructure
- Limit Excessive Motions

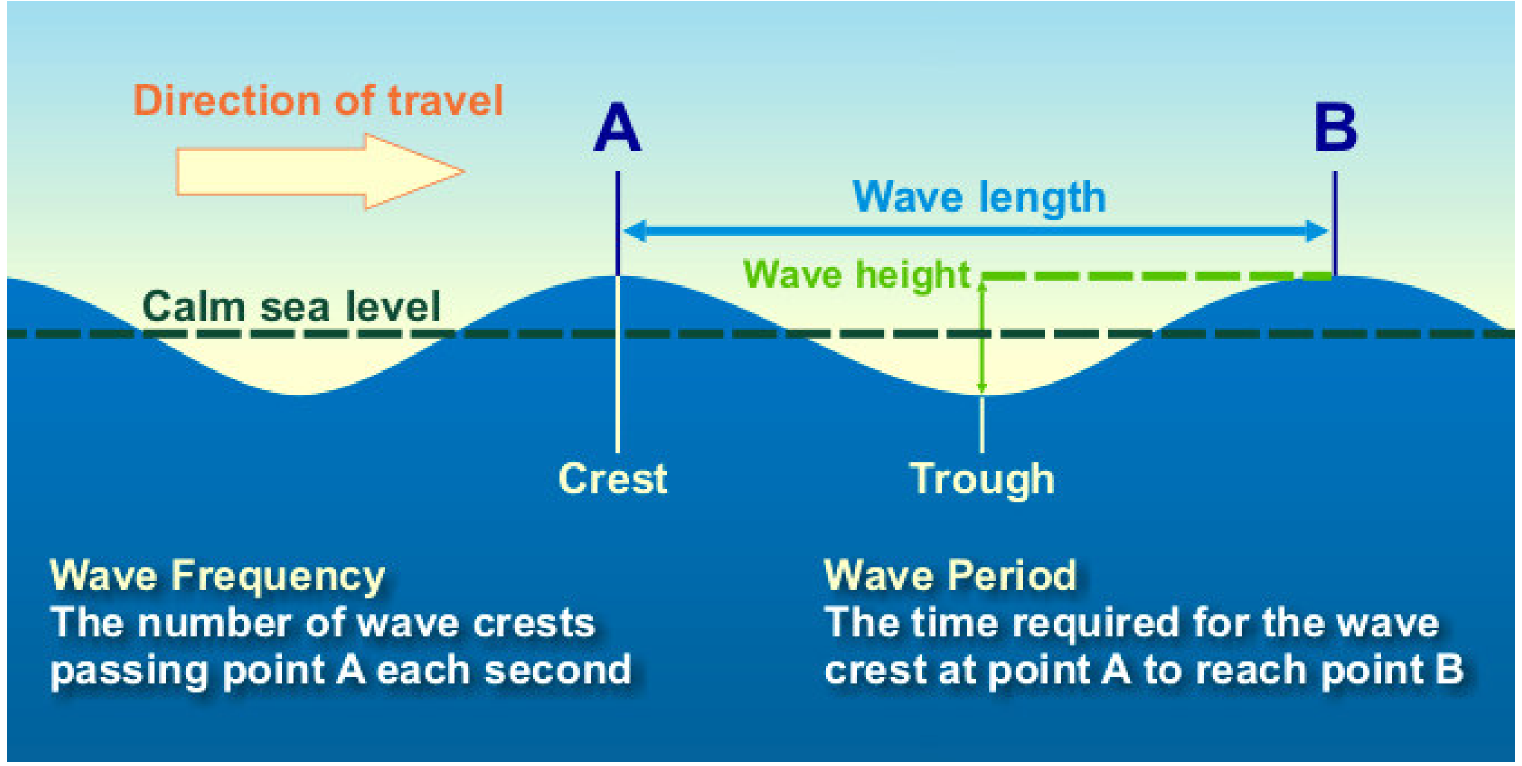
BASIS OF DESIGN FOR WAVE PROTECTION

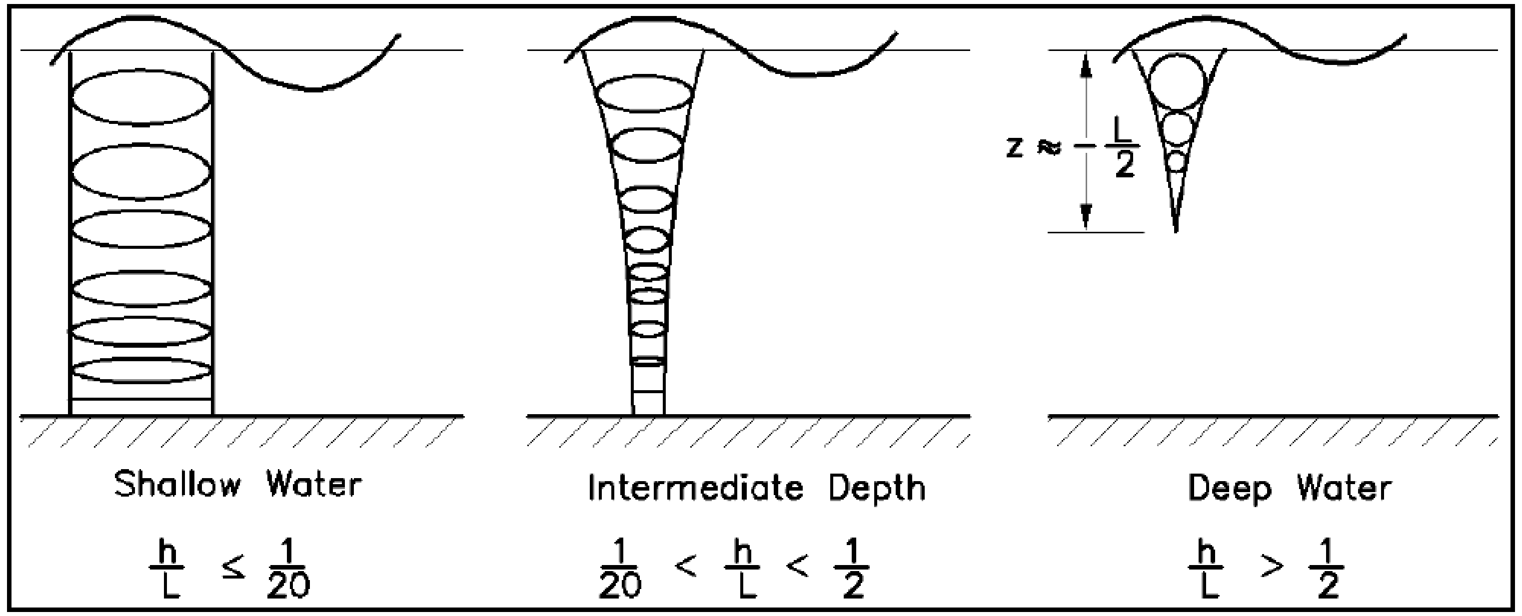
- Standards/Guidelines, e.g.:
  - Australian Standards (2001)
  - ASCE (2012) Planning & Design Guidelines for Small Craft Harbours
- Operational Design Limitations (Serviceability Limit-State)
  - Wave Height Exceeds 1 ft once a year
  - In Port Design, Defined by Combinations of Wave Height & Period
- Extreme Design Limitations (Ultimate Limit-State)
  - Wave Height Exceeds 2 ft once in 50 years

Direction and peak period of design harbor wave	**Significant wave height (H_s)**	
	Wave event exceeded once in 50 years	Wave event exceeded once a year
Head seas less than 2 s	Conditions not likely to occur during this event	Less than 0.3 m wave height
Head seas greater than 2 s	Less than 0.6 m wave height	Less than 0.3 m wave height
Oblique seas greater than 2 s	Less than 0.4 m	Less than 0.3 m wave height
Beam seas less than 2 s	Conditions not likely to occur during this event	Less than 0.3 m wave height
Beam seas greater than 2 s	Less than 0.25 m wave height	Less than 0.15 m wave height

WATER WAVE BASICS

- Pressure Disturbance Through Water
- Movement of Energy (Not Mass)
- Movement Causes Orbital/Elliptical Particle Motion
- Simple Wave Form Referred to as Regular / Monochromatic Wave
- In Deep Water:
  - Wavelength (L) a function of wave period in deep water (wave does not “feel” the bottom)
  - Depth > L / 2
- In Shallow Water:
  - Wavelength (L) a function of wave period and depth (wave “feels” the bottom)
  - Depth ≤ L / 20

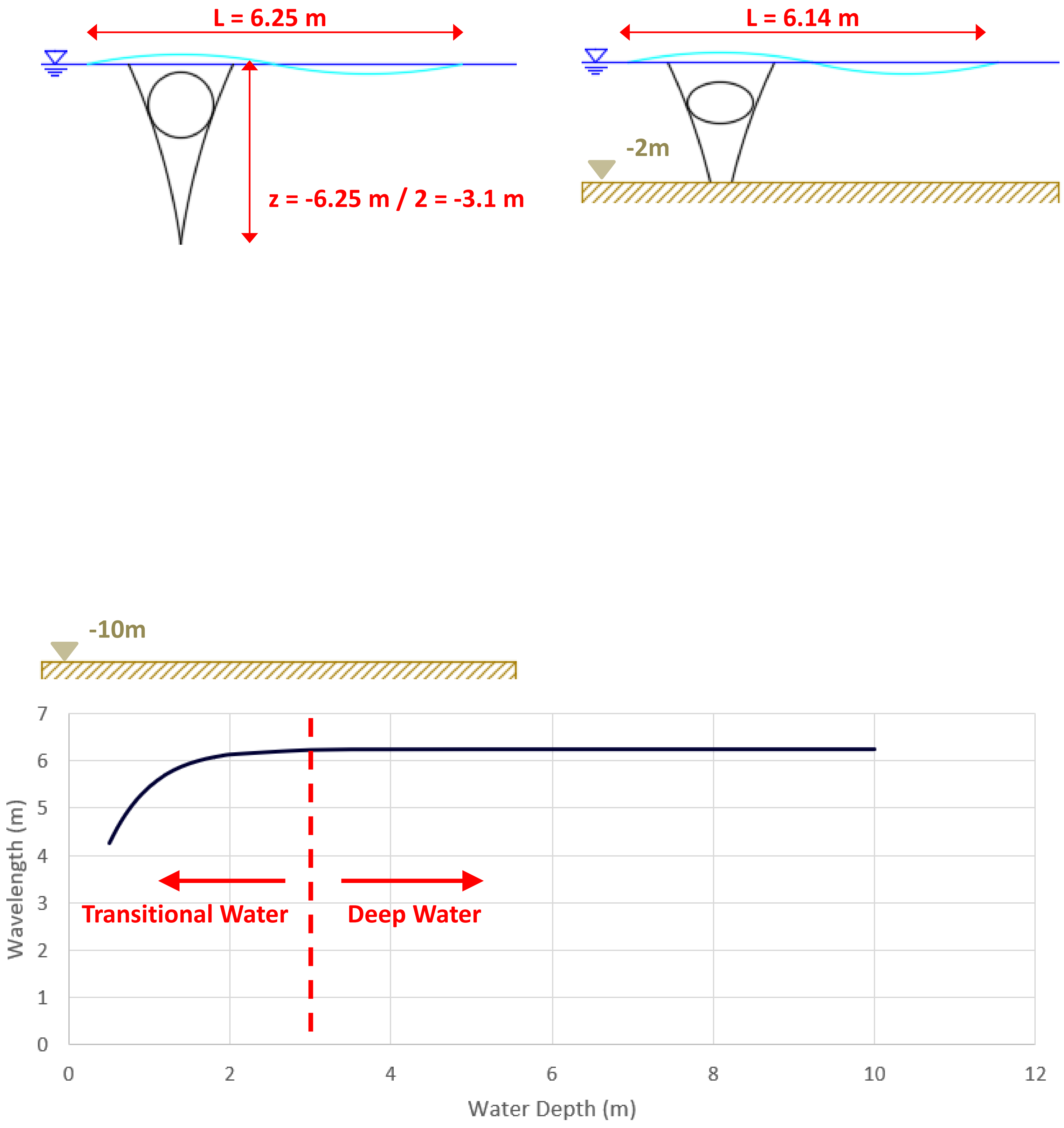




EXAMPLE

- Consider 10 m/s wind blowing across 3 km lake with average depth of 10 m (22 mph winds across 2 mile lake with depth of 33 ft)
- After about a half-hour, the waves will reach:
  - Wave Height Hs = 0.33 m (~1 ft)
  - Wave Period Tp = 2 sec
  - Wavelength L = 6.25m (20.5ft)
- In 10m Depth:
  - Wave Behaves as Deep Water Wave
  - Wave Motions Limited to -3.1 m Depth (= - L / 2)
  - No Wave Motion From -3.1 m to -10 m Depth
- In 2m Depth:
  - Wave Behaves as Transitional Wave
  - Wave "Feels" Seabed
  - Wave Motions Felt Through Water Column

- Consider 12 s Wave in Ocean
  - Deep Water Condition Occurs in Depths > 110m
  - In 20 m (66ft) Depth
    - Transitional Wave
    - Divers Know This Two-And-Fro Sway!



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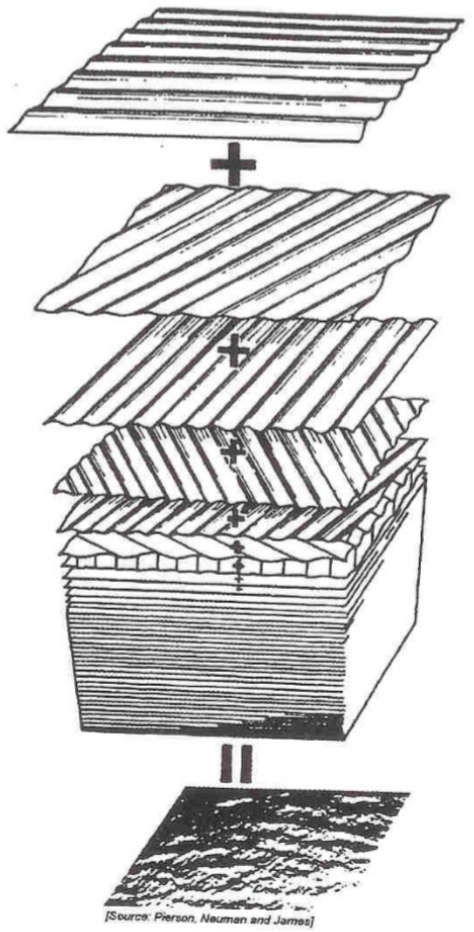
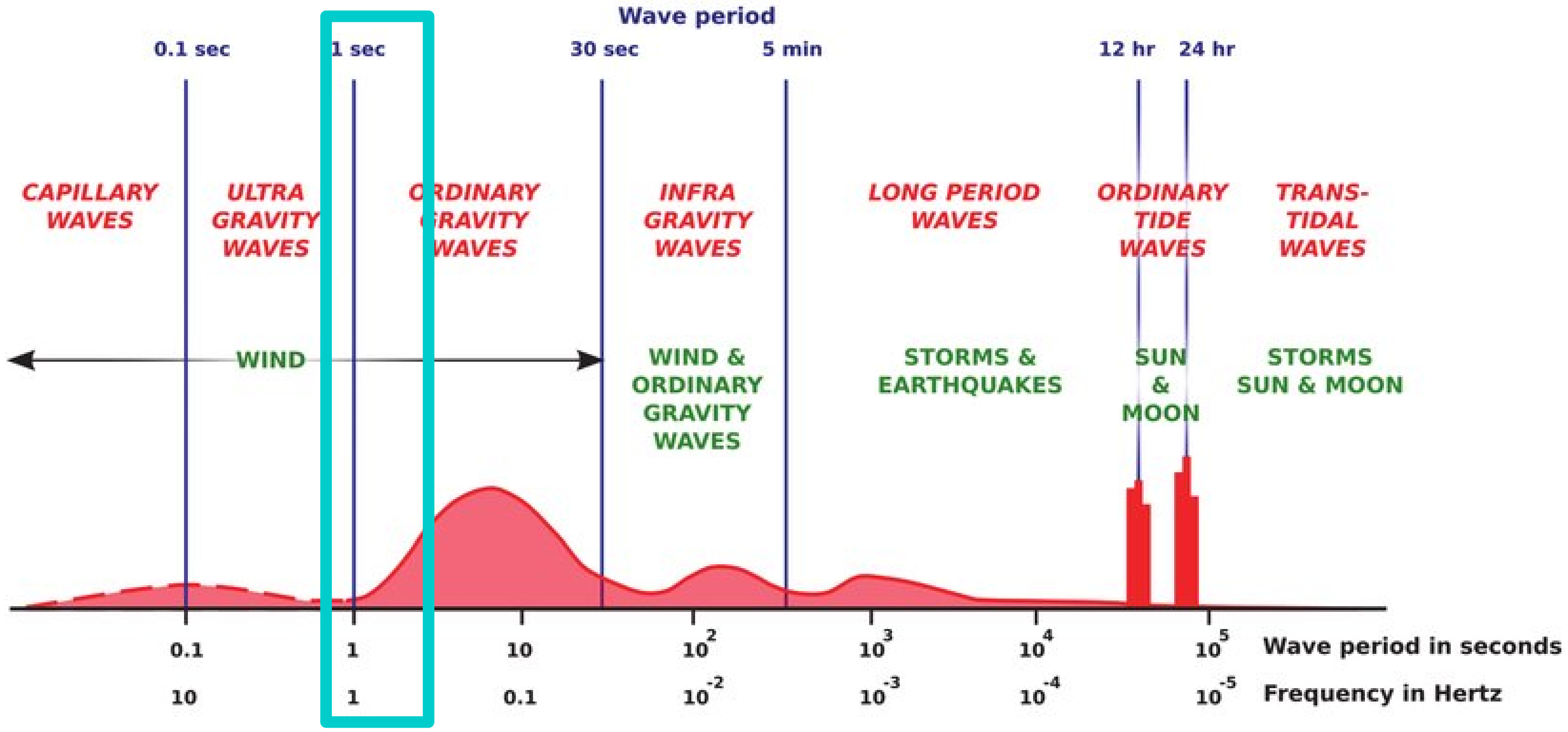
WATER WAVES IN REAL LIFE

- Regular / Monochromatic Wave Simplified Case
- Real Life:
  - Variable Sea State
  - Superposition of Numerous Waves
  - Waves Occur from Boats, Winds, Storms, Astronomical Factors, Etc
  - Each Different Height, Period & Direction
  - Significant Wave Height (Hs) = Highest 1/3 of Waves
- Most Marina Applications:
  - Wind Waves: 1 – 4 sec
  - Boat Wakes: 1 – 3 sec

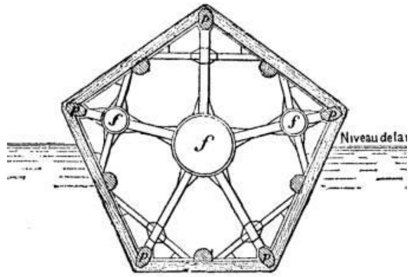


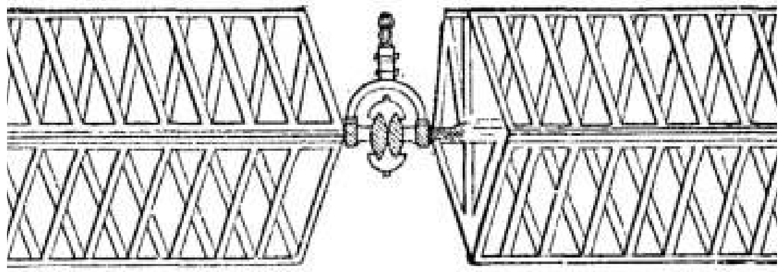


“UNDERSTANDING FLOATING WAVE ATTENUATORS”

FIRST KNOWN FLOATING ATTENUATOR

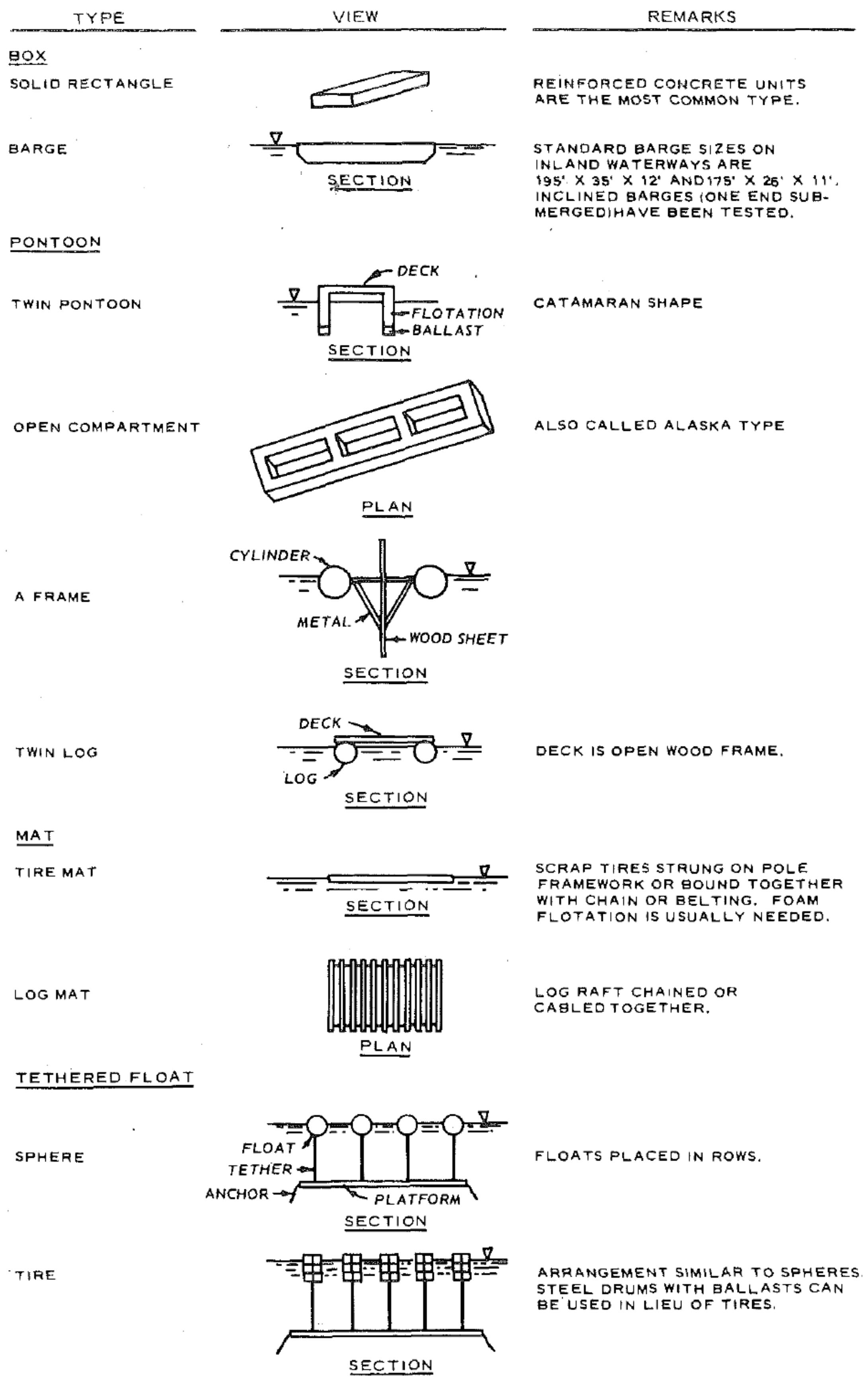
- First known empirical studies on floating breakwater dates back to 1880
- Mr. Tuillard Froideville designed a floating breakwater for the Port of Le Havre, France
- Two lines of a penthagonal framework 25m x 9m x 9m section, installed for total length of 7.5 km





FLOATING ATTENUATORS HAVE EVOLVED

- Various designs and materials have been proposed over the years
- Some categorized them by their geometry/shape:
  - Box
  - Pontoon
  - Mat
  - Tethered
- Others categorized them by primary attenuation mechanism:
  - Reflective
  - Dissipative
  - Both



TYPE	VIEW	REMARKS
BOX		
SOLID RECTANGLE		REINFORCED CONCRETE UNITS ARE THE MOST COMMON TYPE.
BARGE	SECTION	STANDARD BARGE SIZES ON INLAND WATERWAYS ARE 195' X 35' X 12' AND 175' X 26' X 11'. INCLINED BARGES (ONE END SUBMERGED) HAVE BEEN TESTED.
PONTOON		
TWIN PONTOON	DECK, FLOTATION, BALLAST, SECTION	CATAMARAN SHAPE
OPEN COMPARTMENT	PLAN	ALSO CALLED ALASKA TYPE
A FRAME	CYLINDER, METAL, WOOD SHEET, SECTION	
TWIN LOG	DECK, LOG, SECTION	DECK IS OPEN WOOD FRAME.
MAT		
TIRE MAT	SECTION	SCRAP TIRES STRUNG ON POLE FRAMEWORK OR BOUND TOGETHER WITH CHAIN OR BELTING. FOAM FLOTATION IS USUALLY NEEDED.
LOG MAT	PLAN	LOG RAFT CHAINED OR CABLED TOGETHER.
TETHERED FLOAT		
SPHERE	FLOAT, TETHER, ANCHOR, PLATFORM, SECTION	FLOATS PLACED IN ROWS.
TIRE	SECTION	ARRANGEMENT SIMILAR TO SPHERES. STEEL DRUMS WITH BALLASTS CAN BE USED IN LIEU OF TIRES.

WAVE ATTENUATION

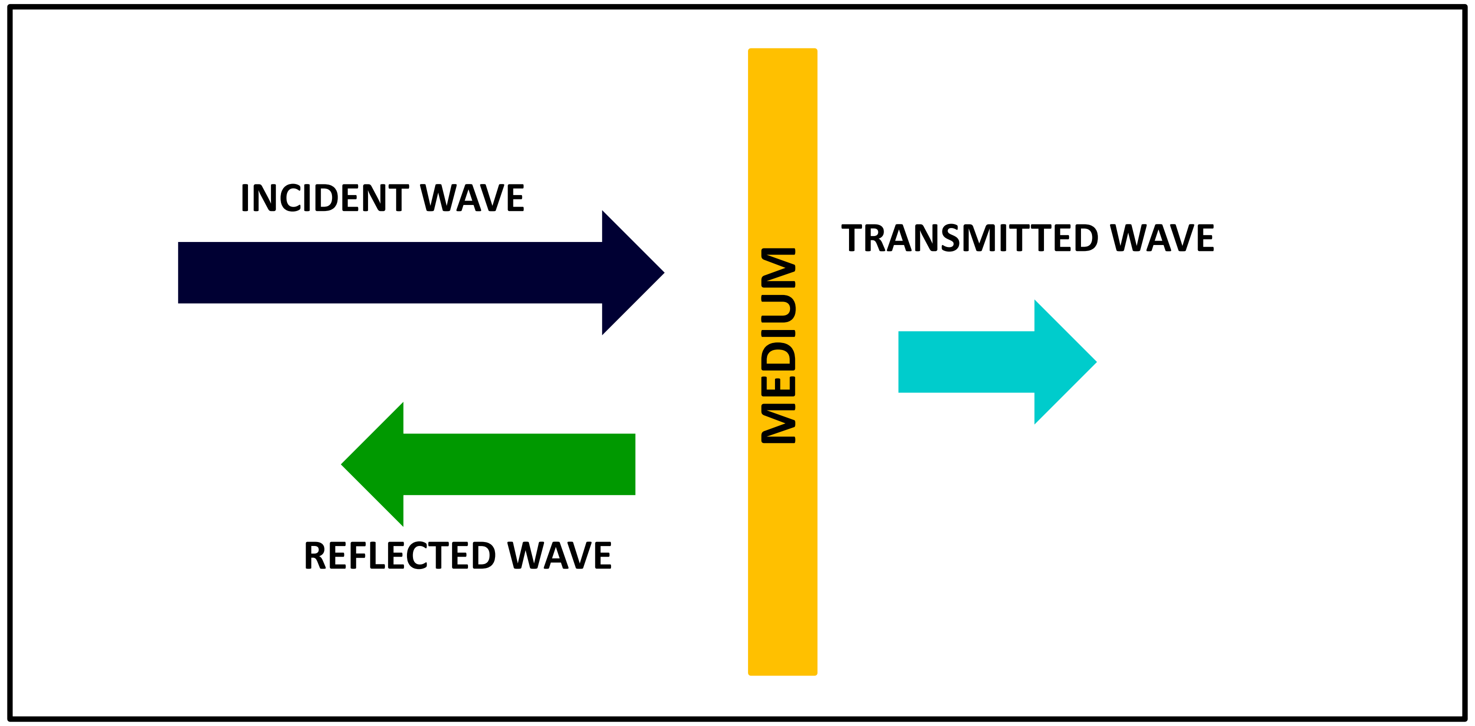
- Wave attenuation is assessed using “Coefficient of Transmission” or C_T:

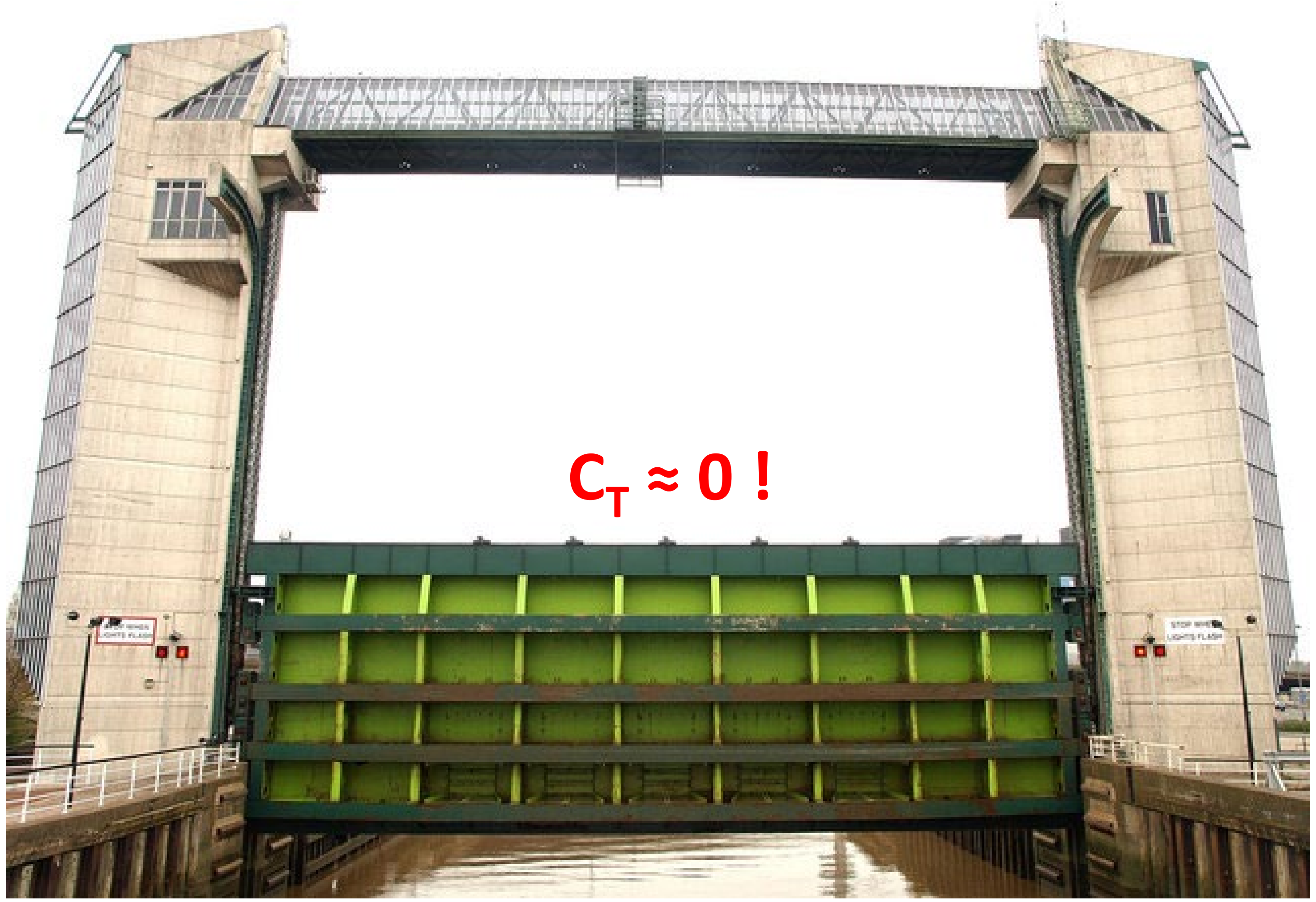
$$C_T = \frac{H_T}{H_I}$$

  - H_T = Transmitted Wave Height
  - H_I = Incident Wave Height

- C_T = 1 means complete transmission of wave transmission
  - Not very effective!

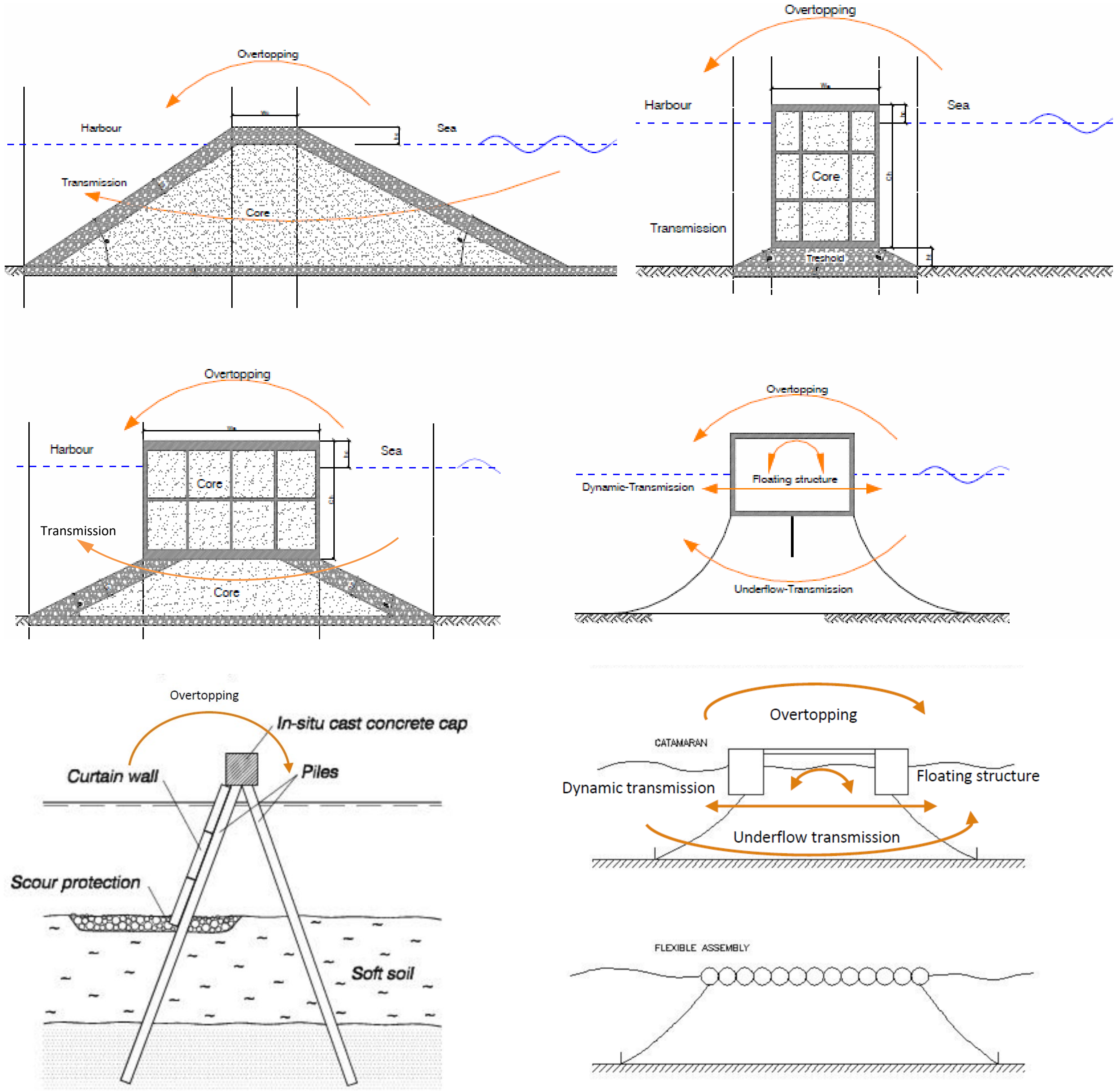
- C_T = 0 means no transmission of wave
  - Solid, impermeable, physical barrier through entire water column
  - Oftentimes not practical:
    - Presents issues with tidal circulation/flow
    - Presents issues with water quality
    - Unsightly if varying water levels
    - Becomes a Fortress as Incident Wave Climate Increases





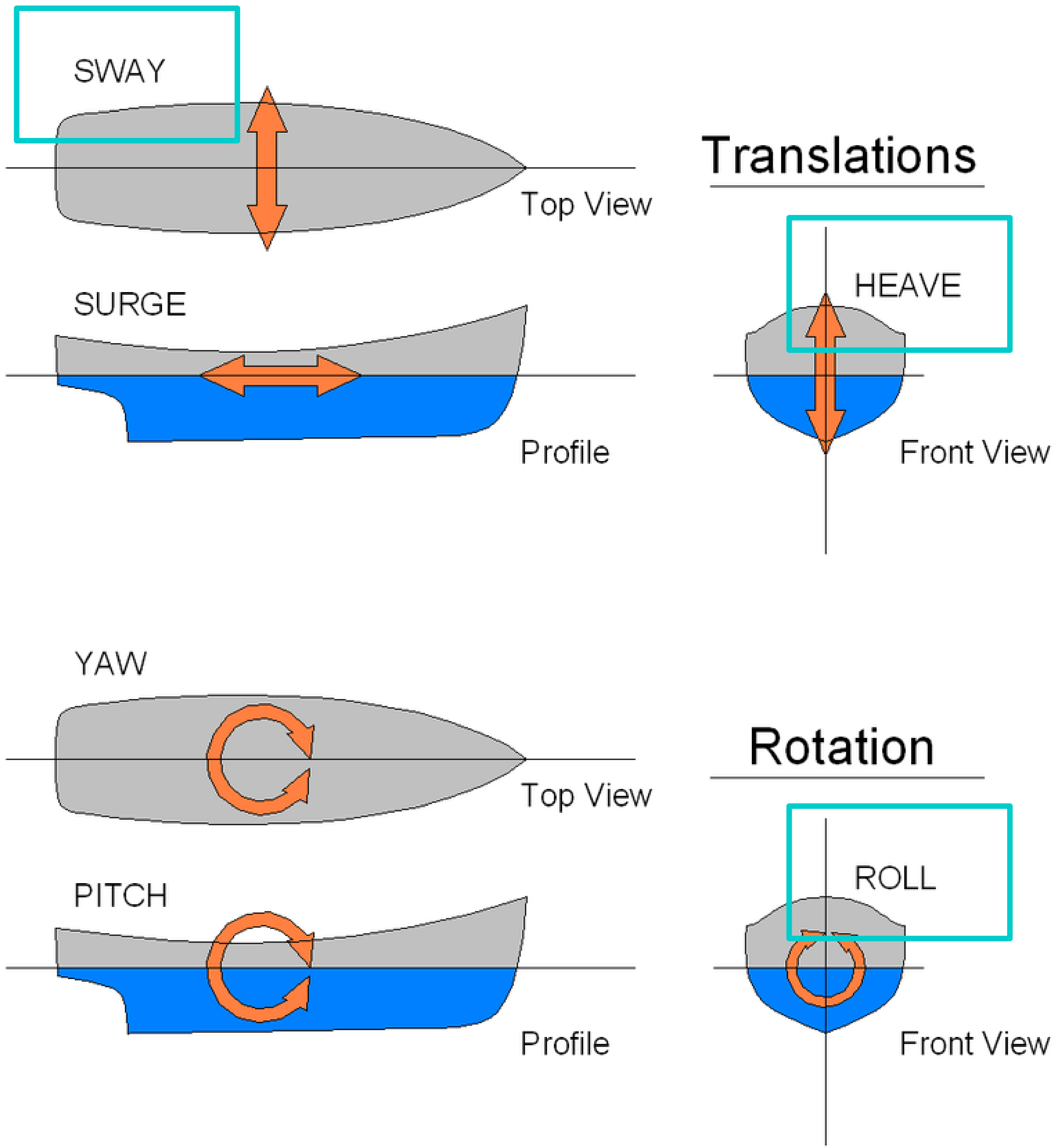
WAVE ATTENUATION IN COASTAL STRUCTURES

- Wave Heights in Lee of Structure Occur From Several Sources:
  - Overtopping
  - Transmission Through Porous Material
  - Underflow Transmission
  - Dynamic Transmission
- Complex Behavior – Particularly for Floating Objects!!



COMPLEX MOTIONS OF FLOATING OBJECTS

- Translations About the Principal Axis
  - Sway
  - Surge
  - Heave
- Rotations About the Principal Axis
  - Yaw
  - Pitch
  - Roll
- Primary Motions Affecting Floating Attenuators Performance:
  - Sway
  - Heave
  - Roll



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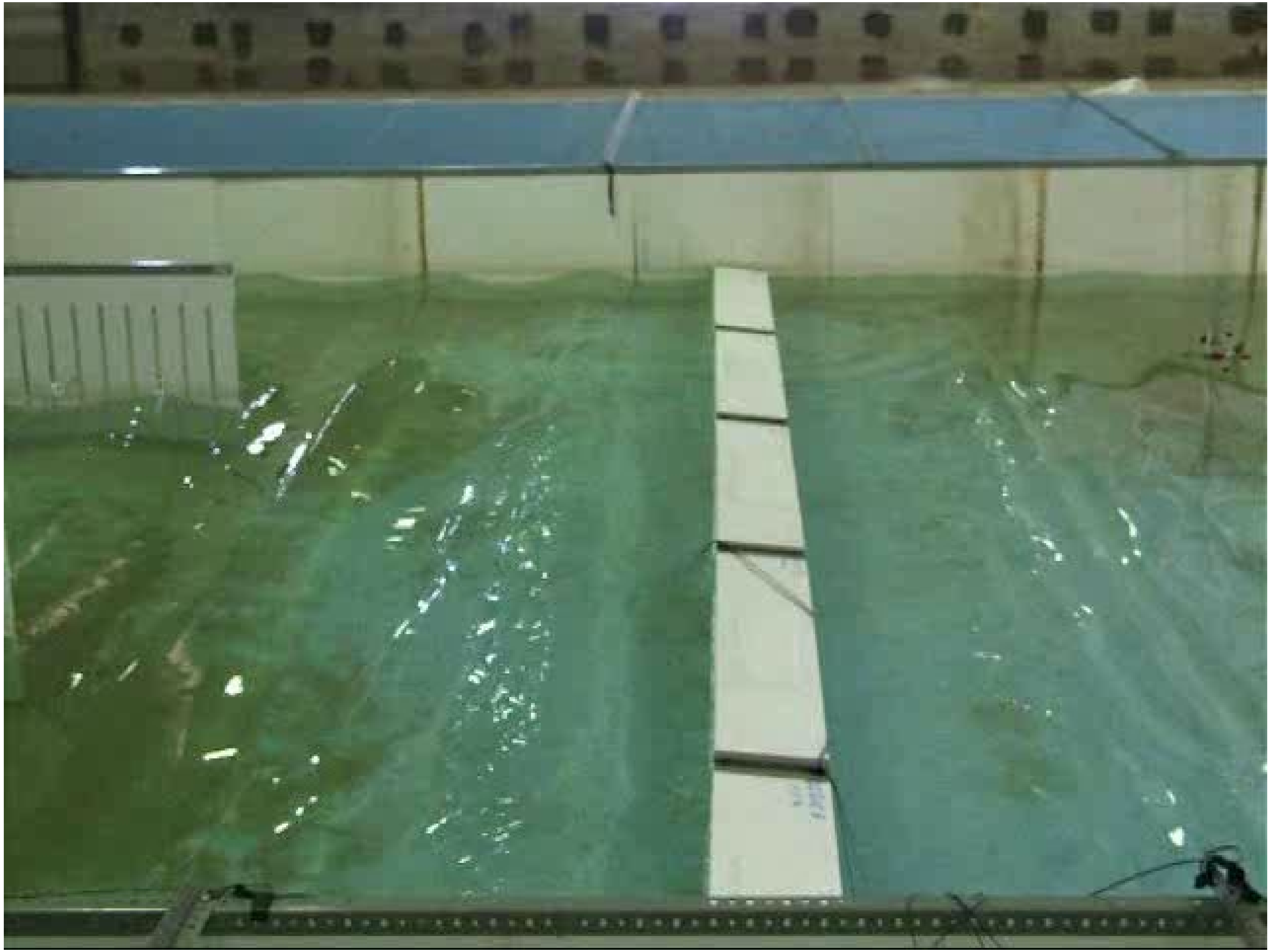
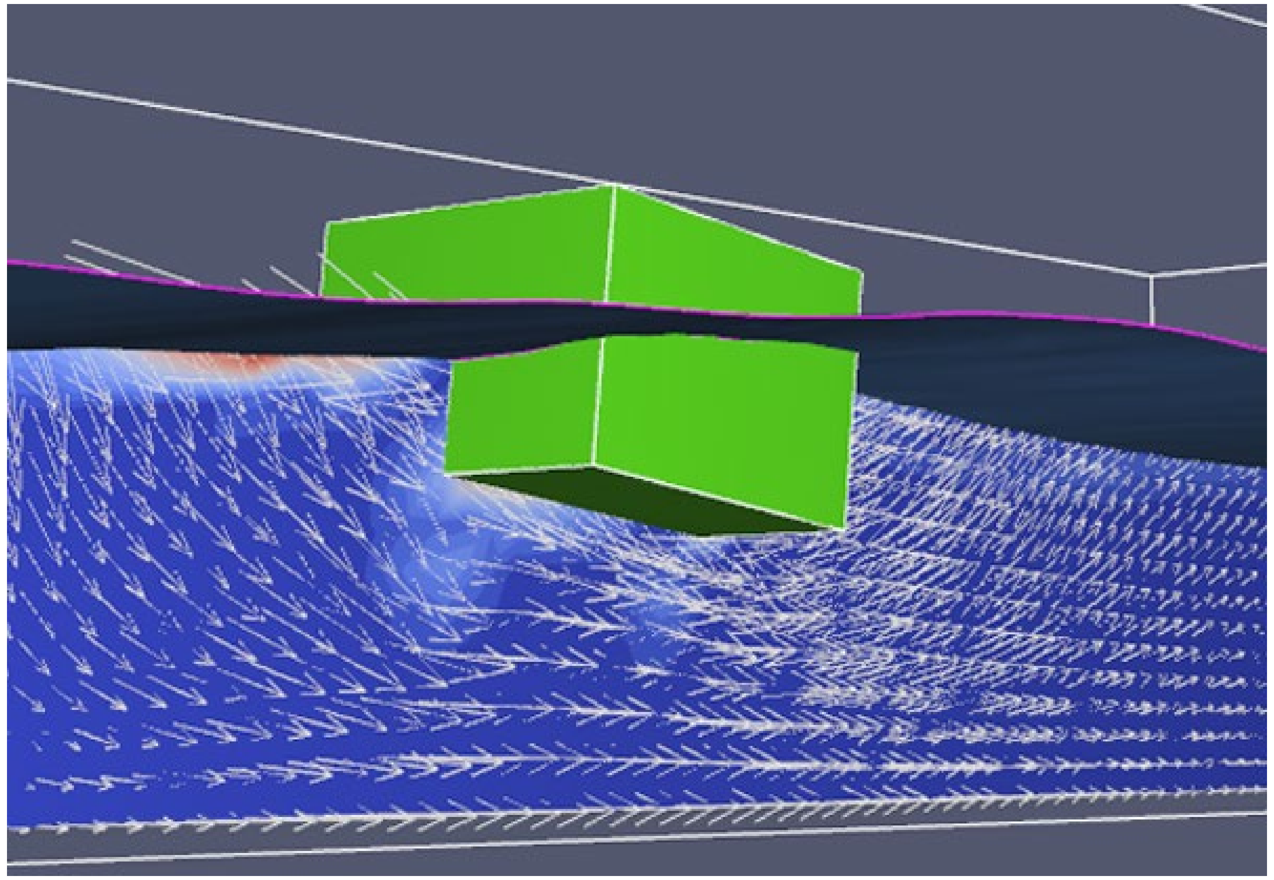
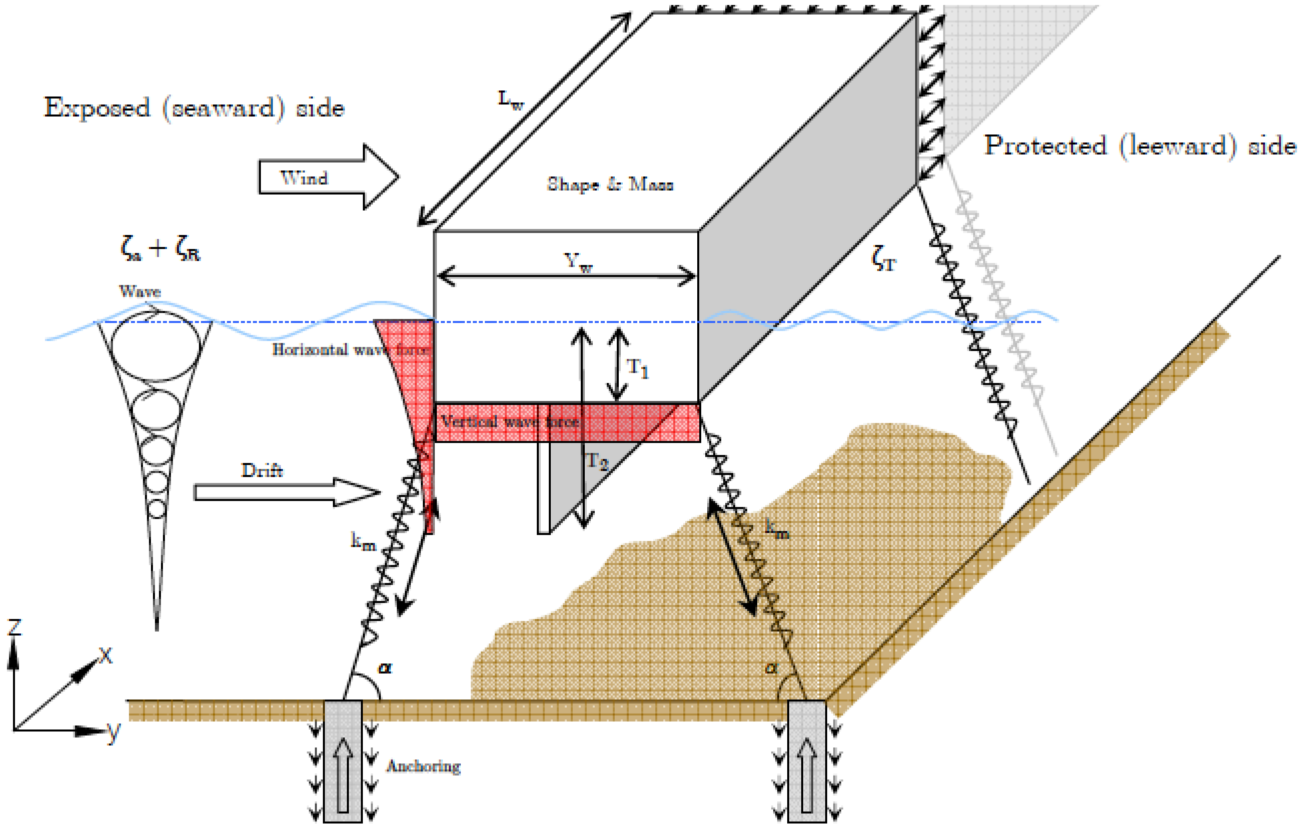


FLOATING ATTENUATOR INVESTIGATIONS

- Intense investigations began in the 1970s and continues today
- Conceptual/scientific studies
- Physical modeling studies
- Numerical (CFD) modeling studies
- Countless studies/investigations from academia
- Limited studies/investigations from product suppliers
- Clear that no product/solution is a “one size fits all”!

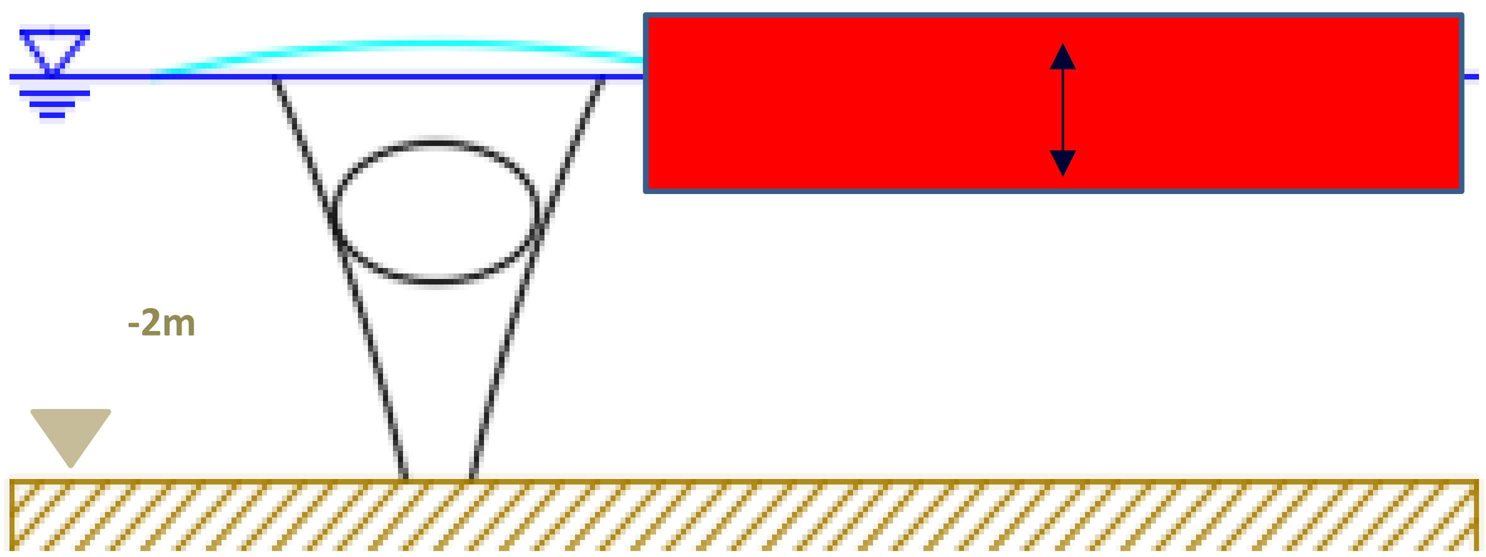




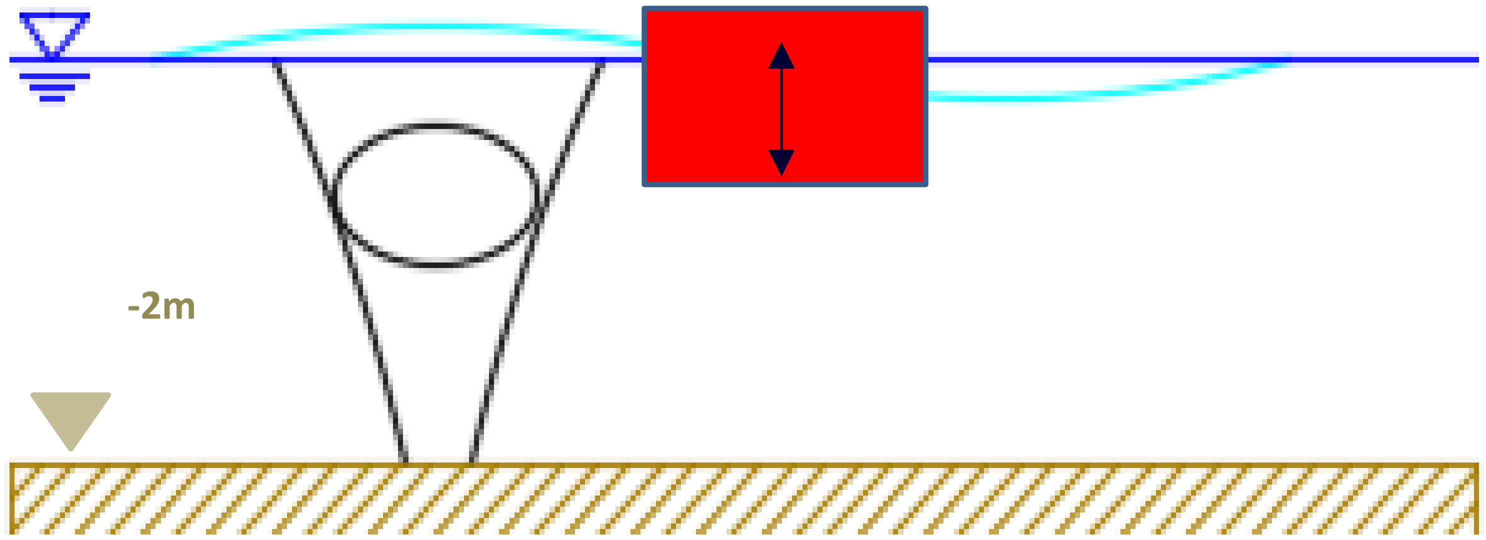
INFLUENCE OF WIDTH

- Generally speaking, increasing width increases attenuation
- Rule of thumb: Width >= 2/3 Wavelength
  - In 4 m depth, 2 sec wavelength = 6 m (20 ft)
  - In 4 m depth, 3 sec wavelength = 14 m (46 ft)
  - In 4 m depth, 4 sec wavelength = 25 m (82 ft)
- Short width responds as "riding the wave"
- Controlling motions of floating object critical to its performance
- Problematic in shallow water with large water level range
- Costly if in deep water

Idealized Schematic



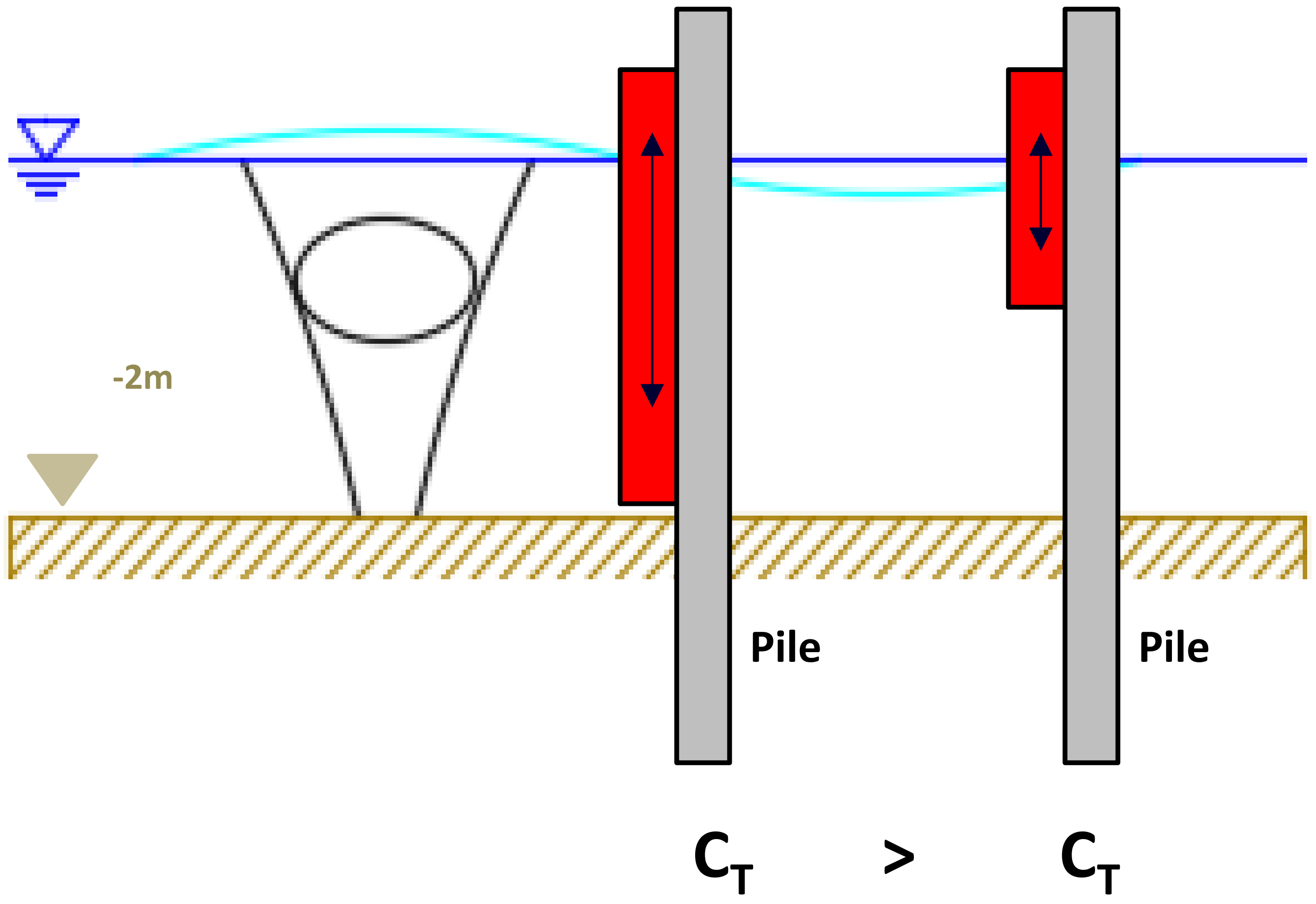
C_T (above) > C_T (below)

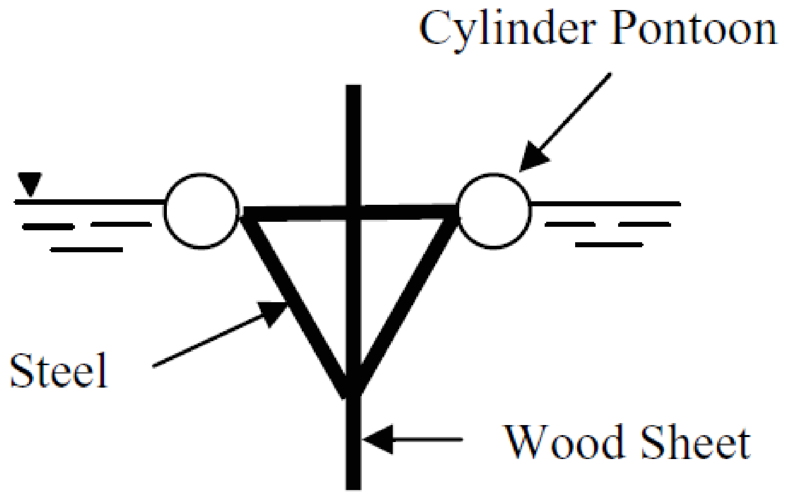


INFLUENCE OF DRAFT

- Generally speaking, increasing draft increases attenuation
- Reflective wave barrier
- Controlling motions of floating object critical to its performance
- Problematic in shallow water with large water level range
- Costly if in deep water

Idealized Schematic



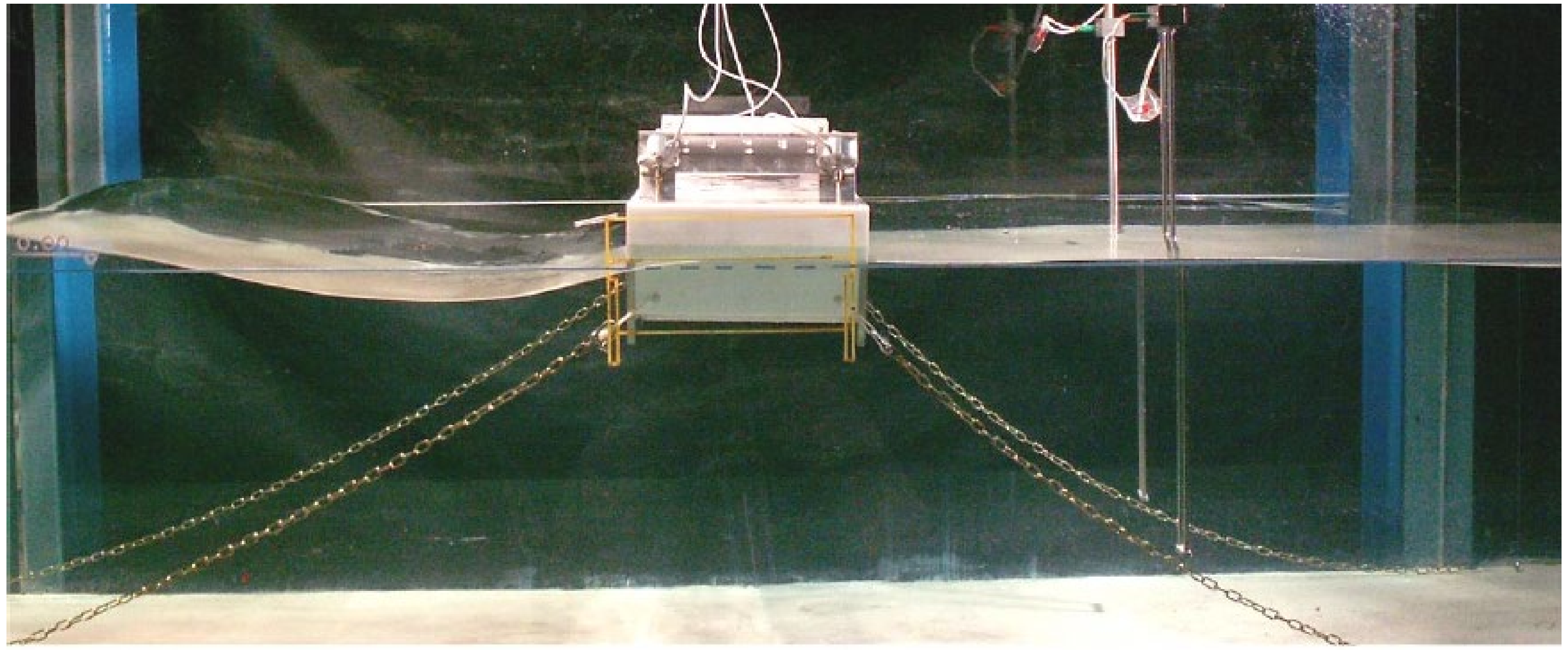


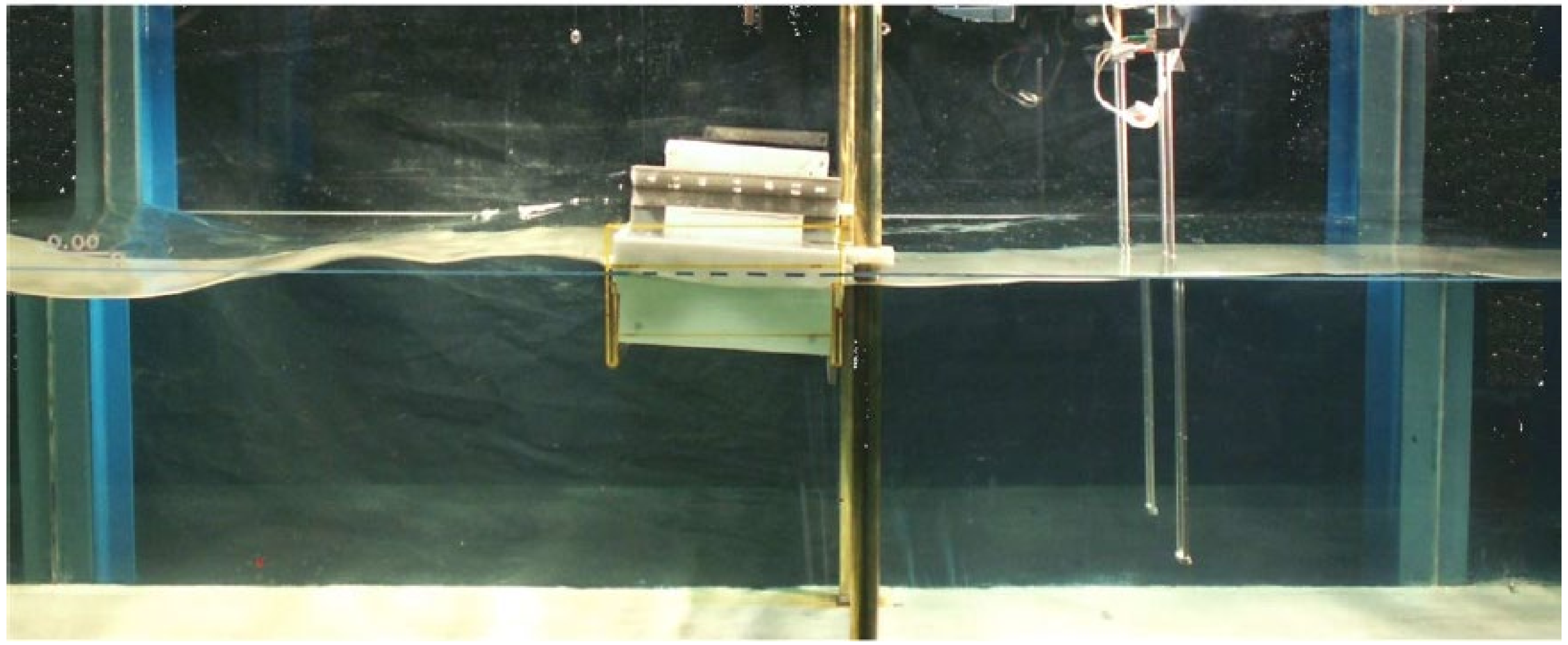
INFLUENCE OF MASS

- Generally speaking, increasing mass increases attenuation
- Helpful in controlling motions of floating object
- Particularly import when anchored by chain or elastic moorings
- More mass typically more costly

INFLUENCE OF ANCHORING

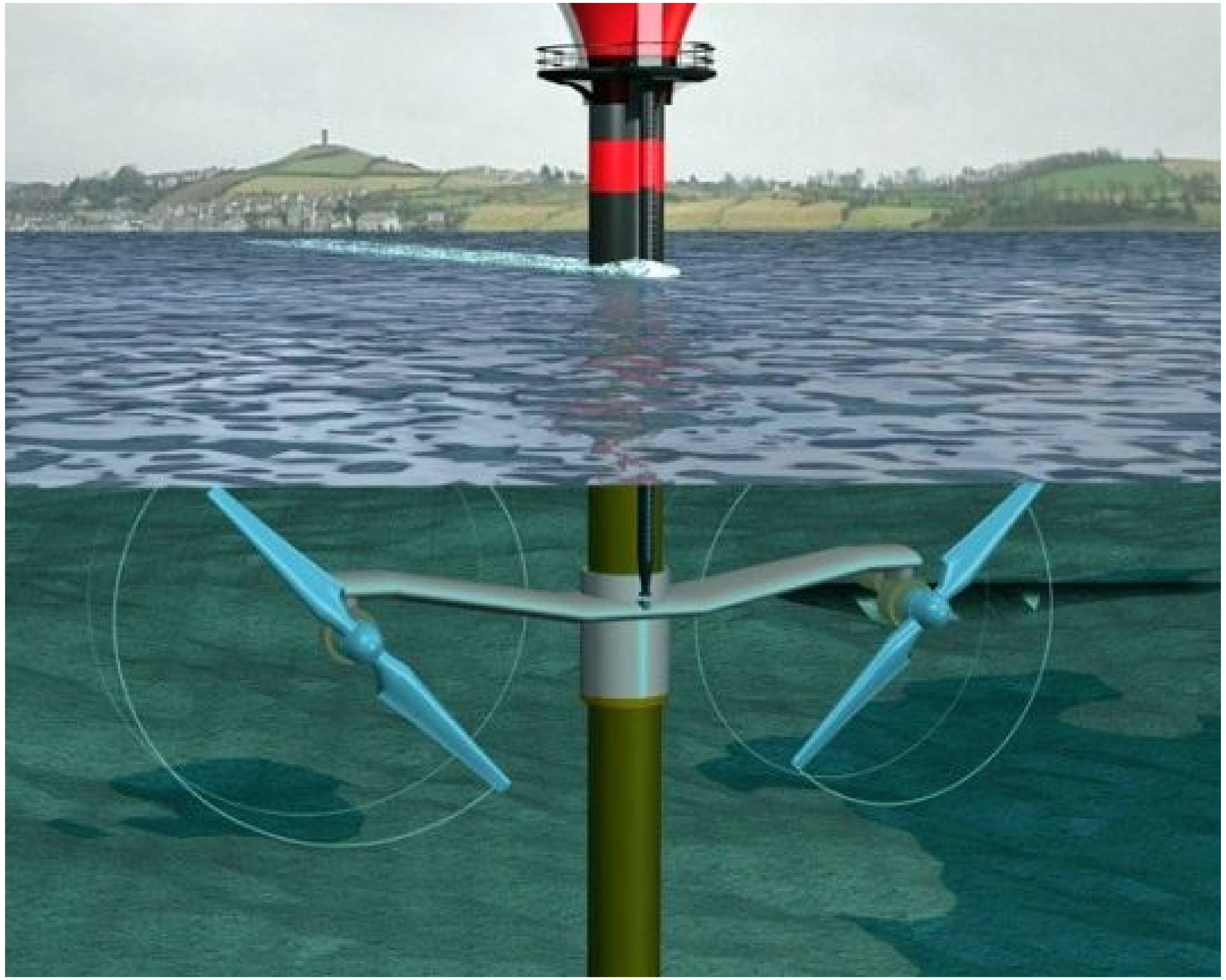
- Guide Piles
  - Limited lateral movement
  - Potential reduced attenuator size due to rigid anchoring
  - High wave loads transferred to mooring piles so requires more piles
  - Pile Position (Inshore, Offshore, Staggered)
- Elastic Mooring Lines
  - Subject to greater movement than piles but less than chain
  - Dampens wave energy through tensioning of elastic lines
  - Reduces wave loads transferred to restraining system
  - Elastic Mooring Position (Crossed, Uncrossed)
- Chain
  - Subject to greatest lateral movement
  - Dampens wave energy through tensioning of catenary lines
  - Reduces wave loads transferred to restraining system
  - Chain Mooring Position (Crossed, Uncrossed)





OTHER CONSIDERATIONS

- Perforations in panels
  - Increase energy loss to turbulence and dissipation
- Sloped panels
  - Separate incident wave from transmitted wave
- Hanging "elements" underneath of floating attenuator
  - Tires
  - Fake kelp/seaweed to encourage marine growth
  - Dissipate undertow transmission
- Spinning/rotating elements
  - Transfer wave energy to renewable energy
  - Lost of energy to transmitted wave



“UNDERSTANDING FLOATING WAVE ATTENUATORS”

SO MANY OPTIONS TO CHOOSE FROM!...HOW TO DECIDE “TRUE” WAVE ATTENUATORS?!?

NEW

FLOATING BREAKWATER / CONCRETE

FLOATING BREAKWATER / CONCRETE

FLOATING BREAKWATER / CONCRETE

FLOATING BREAKWATER / CONCRETE

FLOATING BREAKWATER / THERMOPLASTIC

FLOATING BREAKWATER / CONCRETE

FLOATING BREAKWATER / CONCRETE

FLOATING BREAKWATER / REINFORCED

FLOATING BREAKWATER / CONCRETE

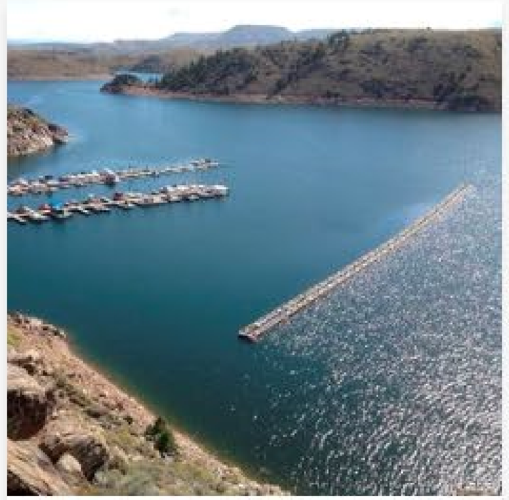
FLOATING BREAKWATER / CONCRETE

FLOATING BREAKWATER / STEEL

FLOATING BREAKWATER

FLOATING BREAKWATER / CONCRETE

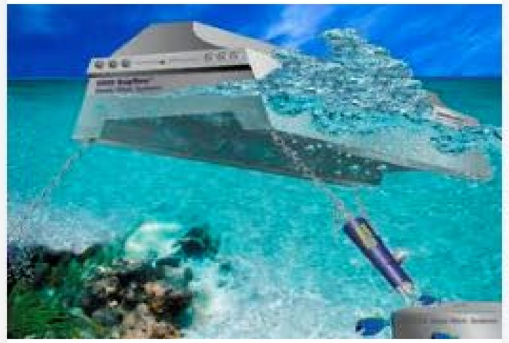
FLOATING BREAKWATER / CONCRETE



FLOATING BREAKWATER

FLOATING BREAKWATER / STONE

FLOATING BREAKWATER / CONCRETE



FLOATING BREAKWATER / CONCRETE

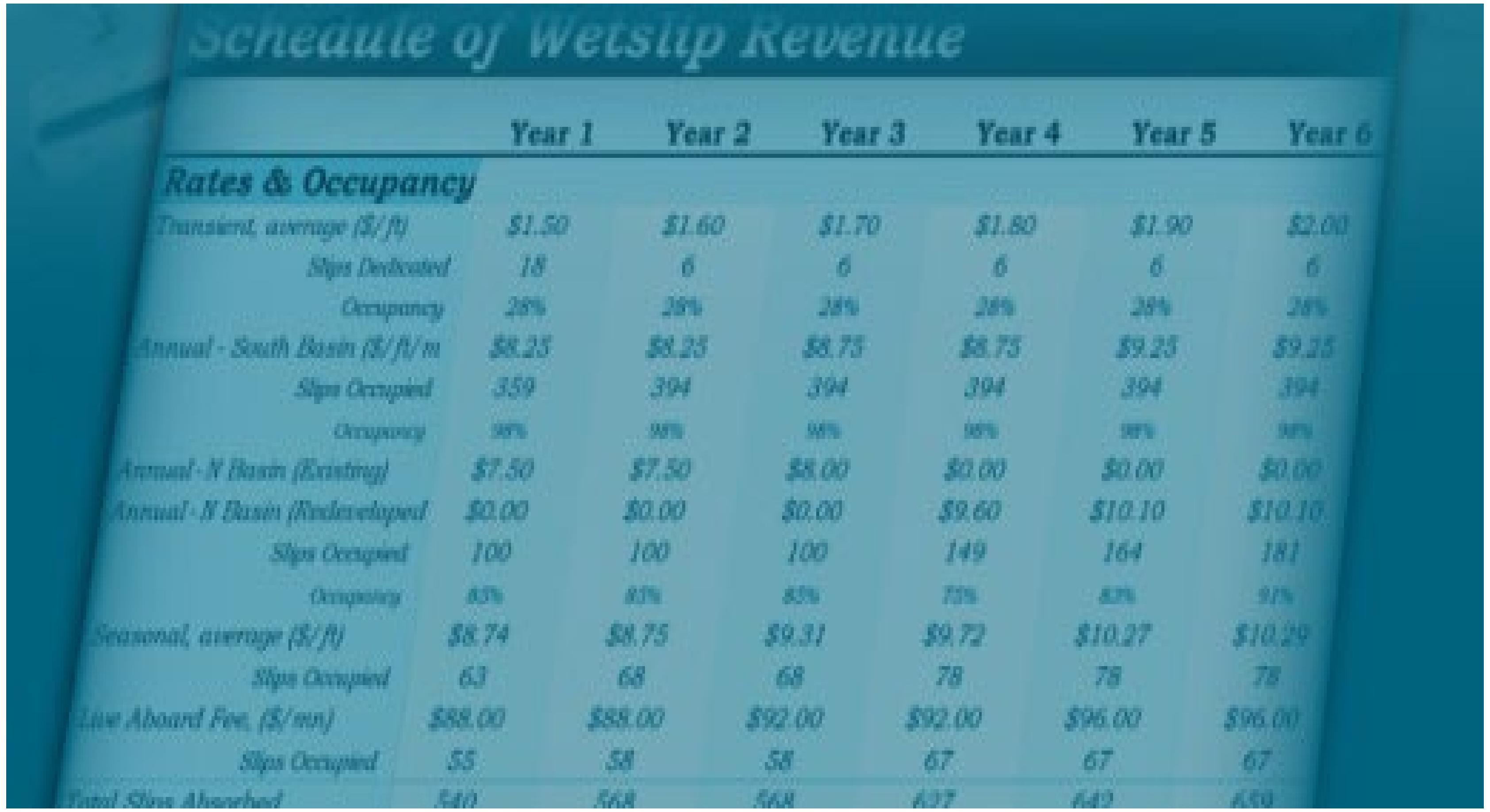
CHOOSING THE RIGHT PRODUCT

- Engage Coastal Engineer / Marina Engineer – Speaks For Itself!
- Establish a Budget
- Establish the Site Constraints
- Identify Operational/Functional Requirements
- Establish Met-Ocean Climate
- Determine Soil/Ground Conditions
- Product & Material Selection
- Address Environmental Impacts

“UNDERSTANDING FLOATING WAVE ATTENUATORS”

ESTABLISH A BUDGET

- Make it Realistic!
- Consultant Can Assist
- Could Range from 25% - 100%+ of Standard Dock Cost Depending on Variety of Factors
- Considering Fabrication Yard (On-Site)
- Do Go Cheap – Safety and Security of the Marina
- Remember – Potential to Earn Revenues



ESTABLISH THE SITE CONSTRAINTS

- Plot/Parcel/Submerged Land Lease Restrictions
- Easements & Zoning Restrictions
- Water Depths
- Entrance Channel/Fairway Navigation
- Space Constraints
  - Restricted Plan Area: Panel Type Products
  - Unrestricted Plan Area: Box Type Products

“UNDERSTANDING FLOATING WAVE ATTENUATORS”

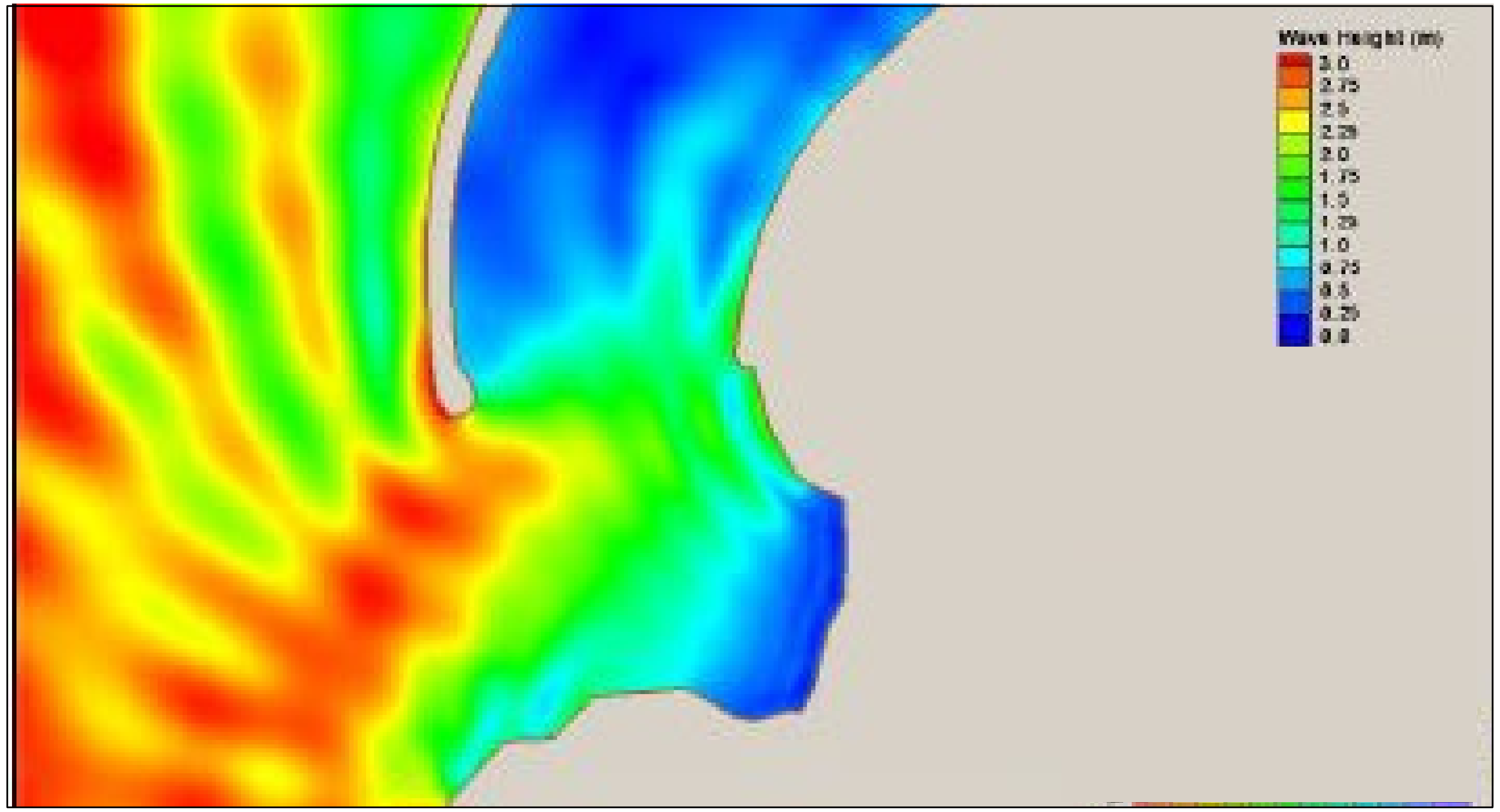
IDENTIFY OPERATIONAL/FUNCTIONAL REQUIREMENTS

- Service Life
- Operational Access
- Aesthetics
- Need to Cater to Transient Demand
- Marina Utilities & Fire/Life Safety Needed
- Connected to or Separated from Marina Docks
- Gangway Location

“UNDERSTANDING FLOATING WAVE ATTENUATORS”

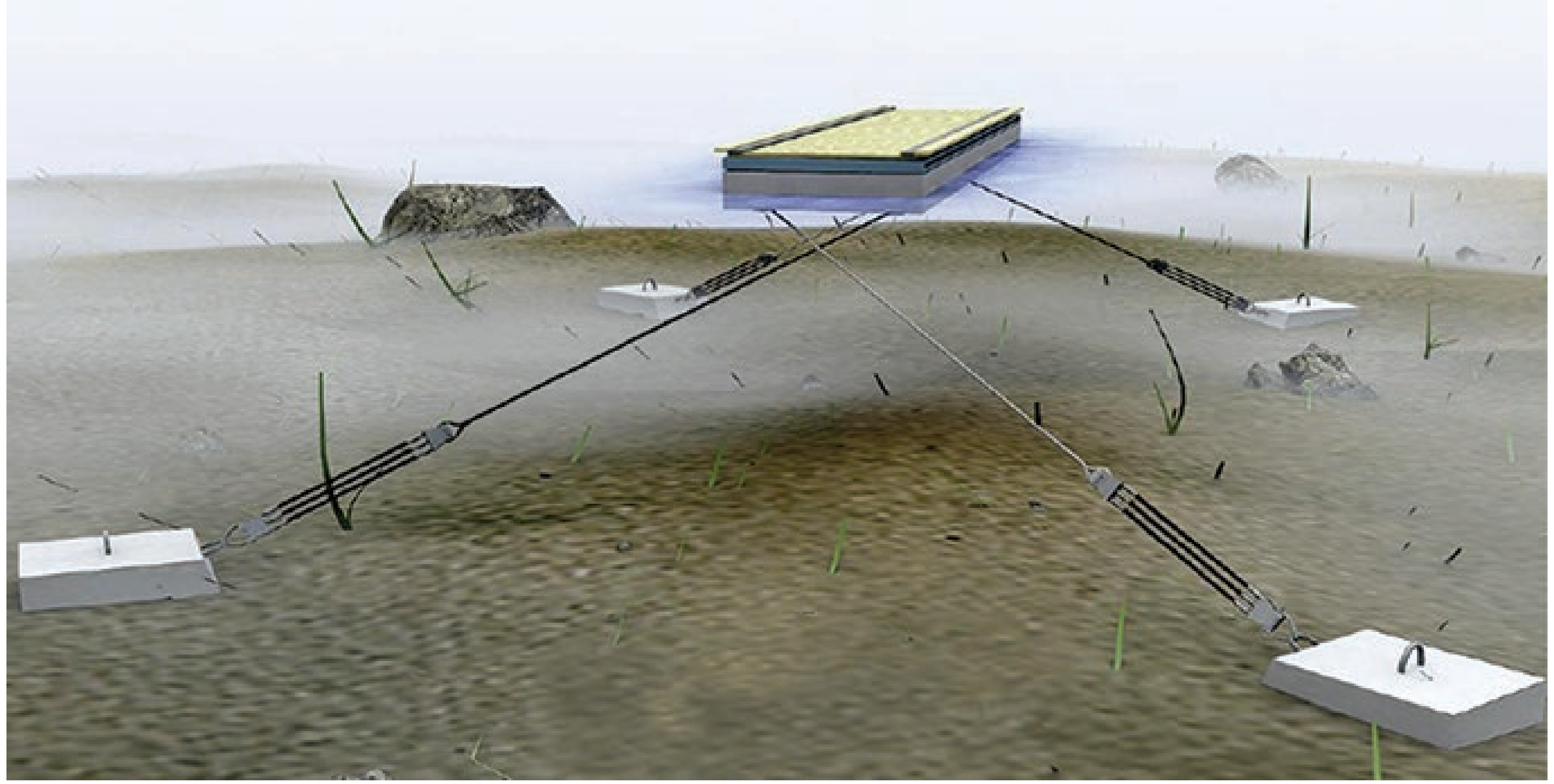
ESTABLISH MET-OCEAN CLIMATE

- Return Period Function of Service Life & Level of Risk
- Water Levels
  - Tidal (Daily Fluctuations)
  - Weekly Variations (Lake)
- Winds
  - Operational
  - Extreme
- Waves
  - Operational
  - Extreme
- Currents
  - Operational
  - Extreme
- Snow/Ice
- Floating Debris



DETERMINE GROUND/SOIL CONDITIONS

- Poor Bearing Soils
  - Pile Anchoring
  - Pile Anchoring & Anchor Block
- Decent Bearing Soils
  - Pile Anchoring
  - Anchor Block & Chain
  - Anchor Block & Elastic Mooring
- Hardbottom
  - Anchor Block & Chain
  - Anchor Block & Elastic Mooring
  - Auger and Cast-In Pile

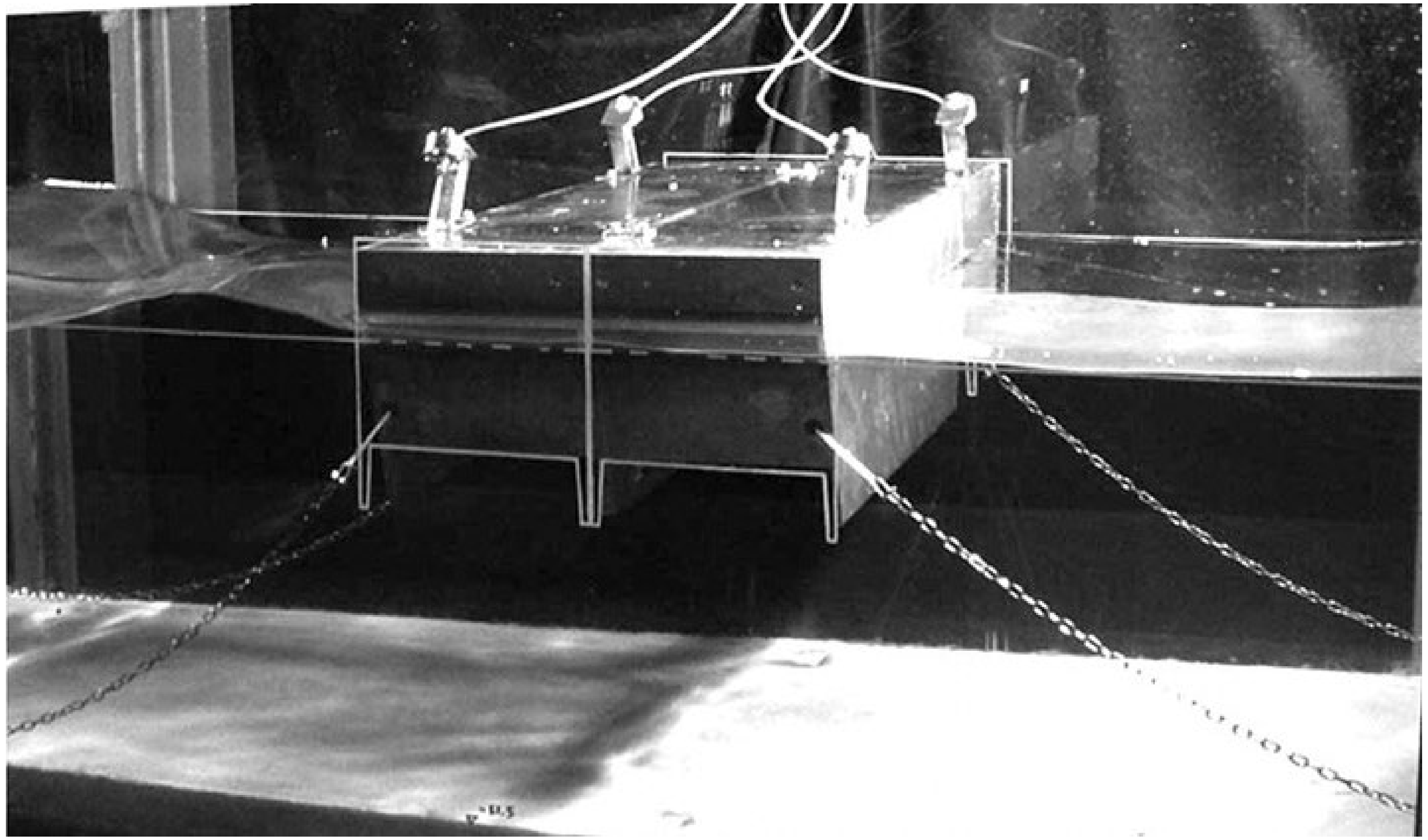


“UNDERSTANDING FLOATING WAVE ATTENUATORS”

PRODUCT & MATERIAL SELECTION

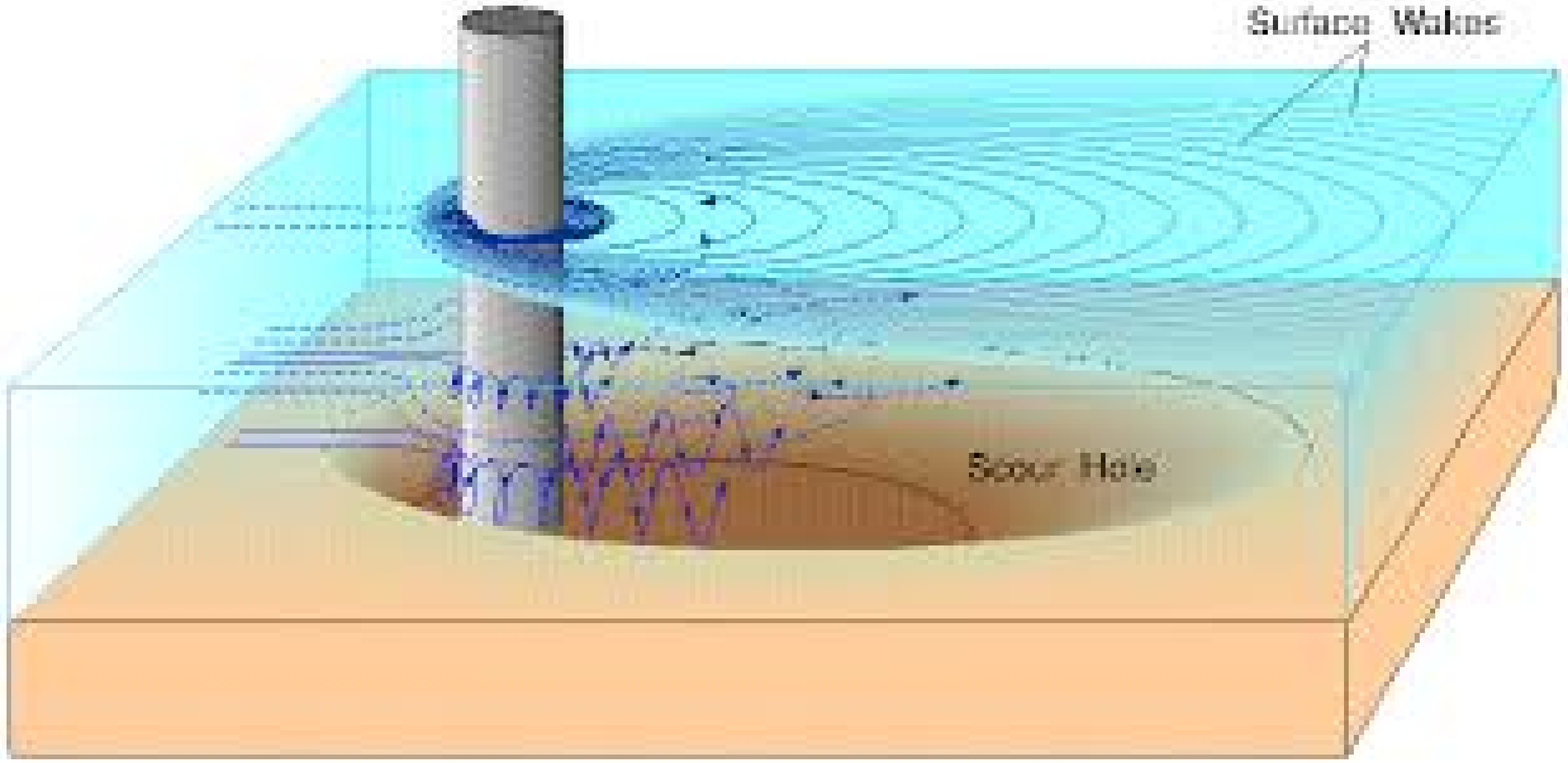
- Off-The-Shelf or Custom/Bespoke Product
- Attenuation Performance
  - Calling a Dock an Attenuator Doesn’t Make it So!
  - Transmission Coefficient for Range of Height & Period
  - Physical Model Study (Should Already Be Off-The-Shelf)
  - Field Investigation Study (Post-Construction)
- Materials
  - Suitable For Life Cycle
  - Fasteners are First To Go
  - Able to Handle Cyclical Loading
  - Locally Available
- Primary Components Near/Above Water Level
  - Easier to Inspect
  - Easier to Maintain

T, sec	H_i, ft	H_t, ft	C_t	H_i/L	W/L
		Plan 1			
2.5	1.5	0.7	0.47	0.047	0.38
	2.0	0.9	0.45	0.063	0.38
	2.5	1.0	0.40	0.078	0.38
3.0	1.5	0.7	0.47	0.033	0.26
	2.0	1.0	0.50	0.043	0.26
	2.5	1.4	0.56	0.054	0.26
3.5	1.5	1.2	0.80	0.024	0.19
	2.0	1.6	0.80	0.032	0.19
	2.5	1.9	0.76	0.040	0.19
	3.0	2.3	0.77	0.048	0.19



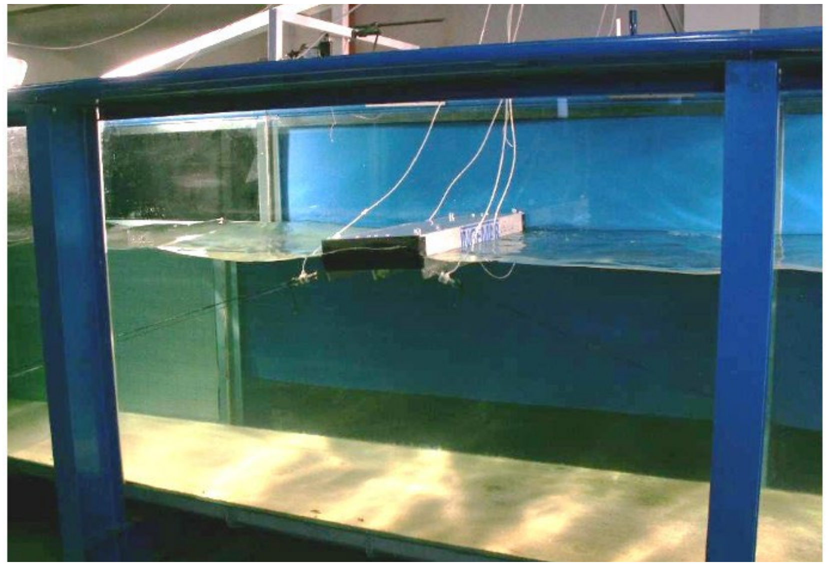
ADDRESS ENVIRONMENTAL IMPACTS

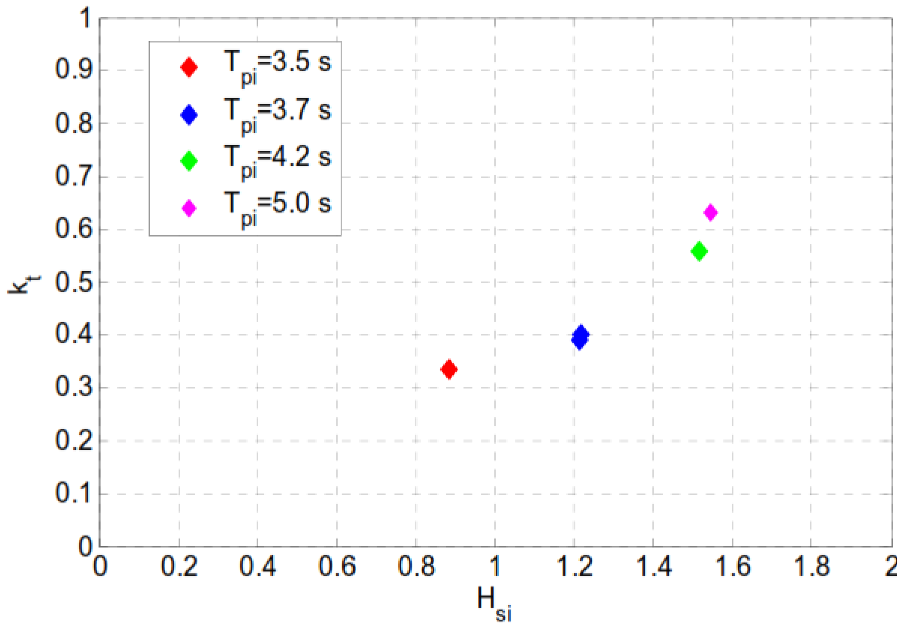
- Extent of Blockade/Barrier
  - Tidal Flow
  - Water Quality/Circulation Concerns
  - Scour of Seabed
- Anchoring Concerns
  - Seagrass
- Other

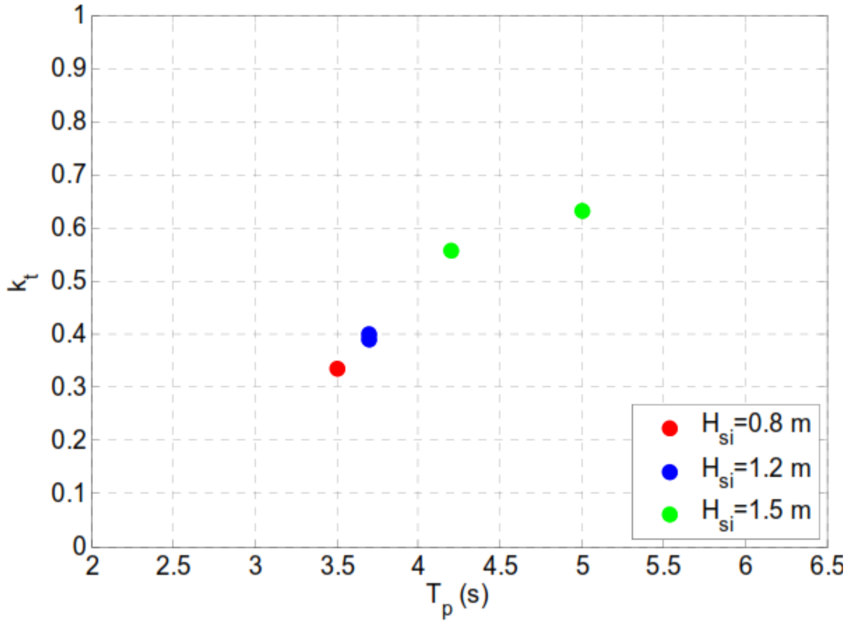


EXAMPLE BOX ATTENUATOR WITH SKIRTS

- Dimensions: 20 m x 6 m x 2.4 m
- Displacement: 120 mt
- Live Load: 5 kPa
- Freeboard: 0.80 m
- Draught: 1.60m

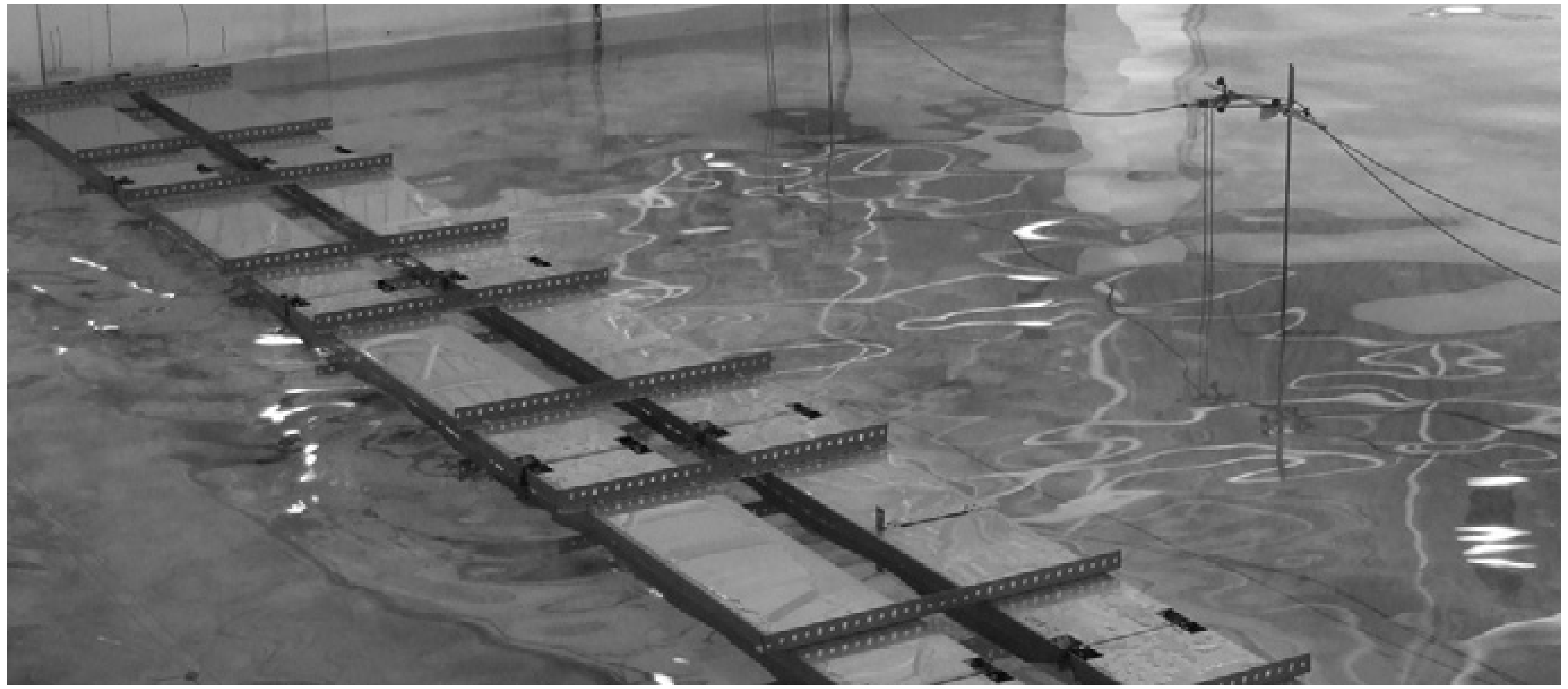


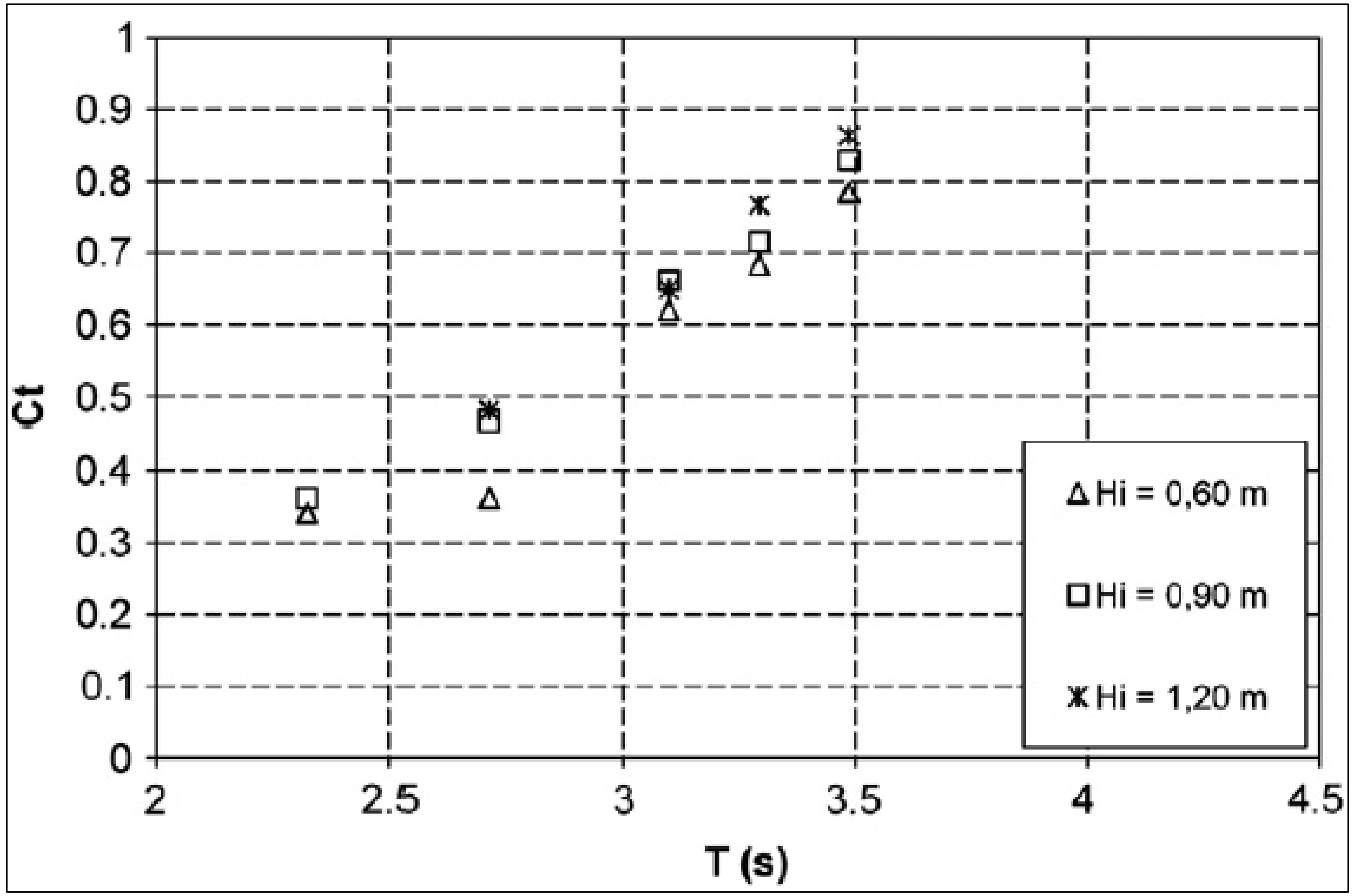




CONCLUSION

- Floating wave attenuators are complex engineered structures
- There are many factors that affect the performance of wave attenuators (width, draft, mass, anchoring, etc)
- A "one-size-fits-all" floating wave attenuator does not work
- Floating wave attenuators require proper design specific to the site's conditions
- Information on floating wave attenuators performance from commercial product suppliers is generally inadequate
- Frequently technical data is unavailable or any such technical data is often oversimplified without proper supporting documentation
- Documented physical model (wave flume studies) should be performed prior to construction and installation – use it as a marketing tool!!
- As alternative, require field studies be performed after installation as part of construction contract / performance guarantees





"UNDERSTANDING FLOATING WAVE ATTENUATORS"

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IMAGES/VIDEOS USED IN THIS PRESENTATION OBTAINED FROM FOLLOWING SOURCES AND/OR GOOGLE (NO PARTICULAR ORDER):

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THIS CONCLUDES THE COURSE PRESENTATION TITLED:

"UNDERSTANDING FLOATING WAVE ATTENUATORS"

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THANK YOU! **QUESTIONS?**

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