Rubble Mound Breakwaters, Timber Crib Construction

MEMORIAL UNIVERSITY

FACULTY OF ENGINEERING & APPLIED SCIENCE

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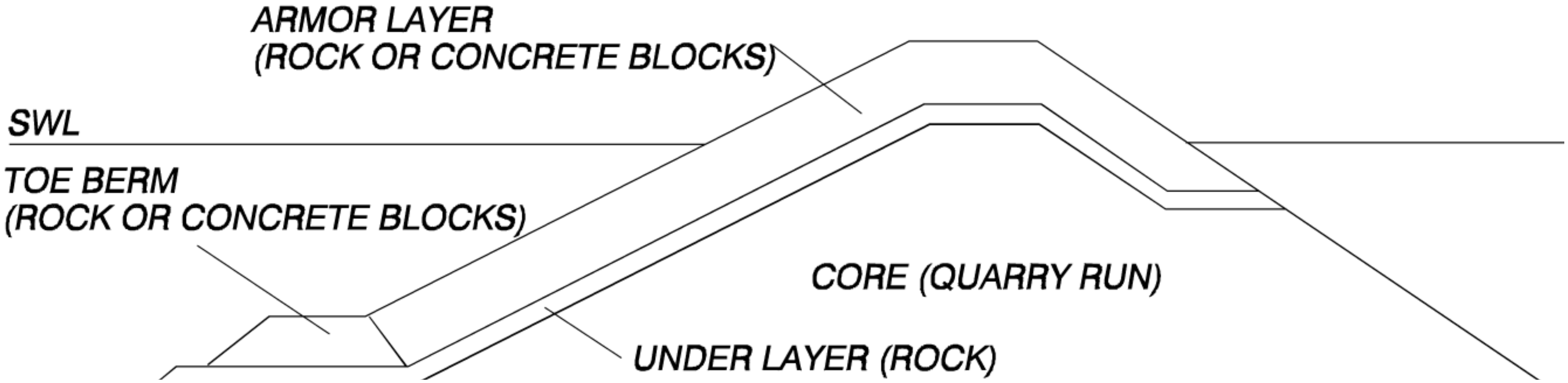
Lecture Outline

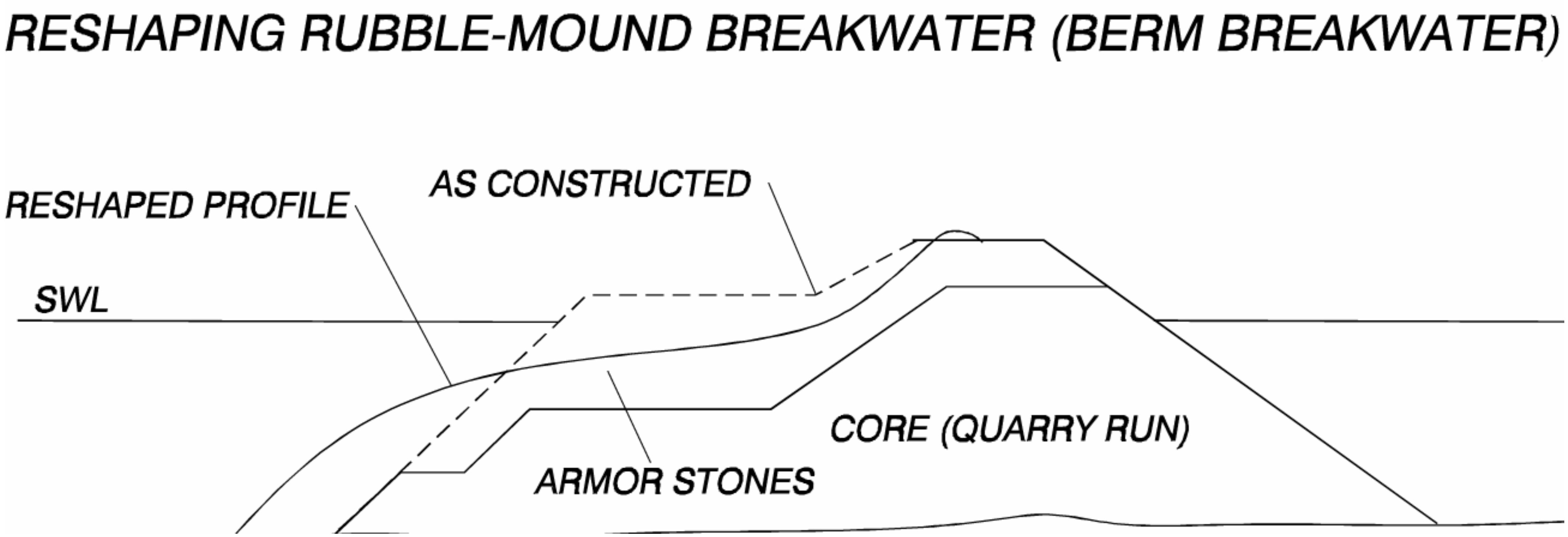
Outline the theory behind and general structure of rubble mound breakwaters, along with the general processes and concepts associated with the construction of a timber crib wharf.

CONVENTIONAL MULTI-LAYER RUBBLE-MOUND BREAKWATER



St. Bride's Breakwater

Berm Breakwater Design



Berm design allows for use of armour less then theoretically required, as additional volume of armour allows for the natural settling of the site to ocean currents and waves.

Bauline, Newfoundland

Concrete Armour Units

Figure VI-2-24 shows examples of the many existing types of concrete armor units.

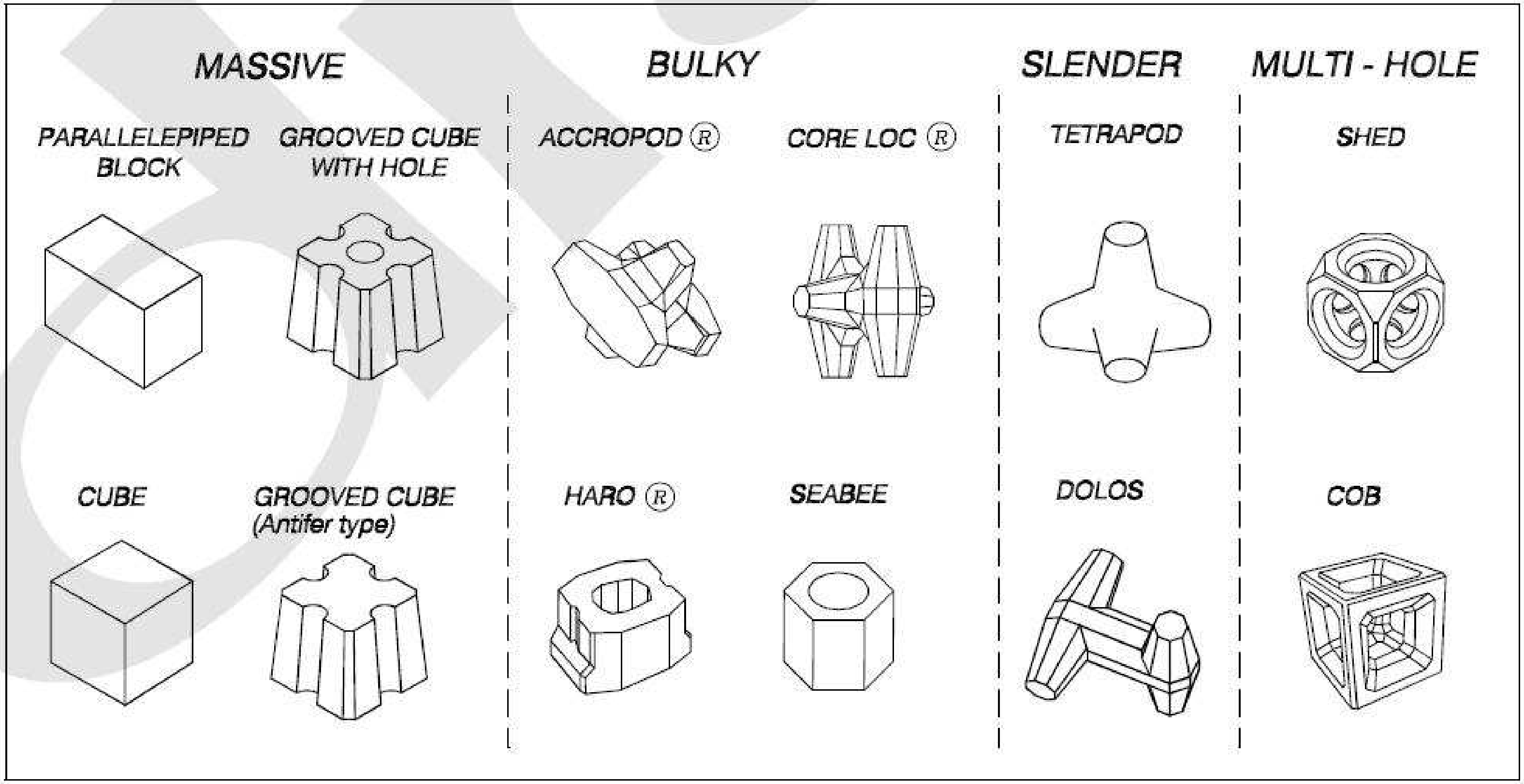


Figure VI-2-24. Examples of concrete armor units

Tetrapods

Recurved Structure

- Prevents overtopping
  - Wave/Spray directed back
- Incorporated into Crib Design (save $)
  - No rubble mound req'd
- Little wave dissipation
  - Reflected
- Possible Navigational Hazard
  - Can create unique wave forms

Portugal Cove South, NL

Timber Crib Wharf - Selection

- Soil
  - Bearing Capacity
  - Sliding Forces
- Depth
  - Too deep, cost prohibitive
- Wave Action
  - Wave forces

Timber Crib Wharf - Selection

- Simple Design
- Easily Repaired
- Acts as breakwater (upto medium size waves)

Foundations

- Bedrock
- Rock Mattress
- In-situ soil
- Dredging Required

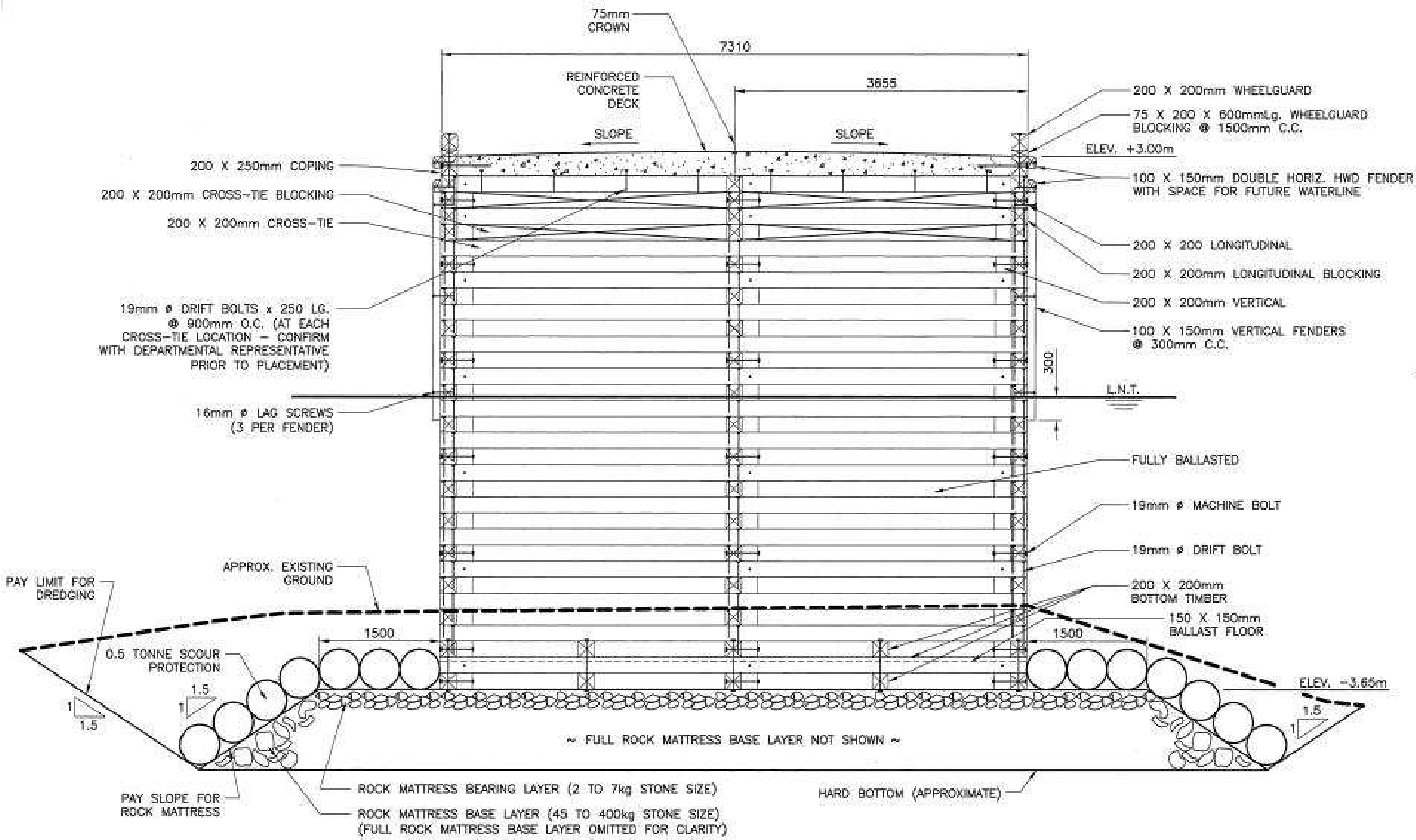
Crib – Bottom Timbers

Crib – Before Launch

- Erected to +0.4 LNT
- Verticals
- Ballast Floor
- Treated Butts

Timber Crib Construction

Crib Construction – Cross Section



Crib Placement (Below +0.4 LNT)

Marrying Cribs (Above 0.4 LNT)

- Butt ends to land in middle of crib bays
- Scatter location of joins evenly throughout

Crib Ballast

- Concrete
  - Tremie Pipe
- Rock (300mm)
  - Distribute evenly among bays until completely sunk

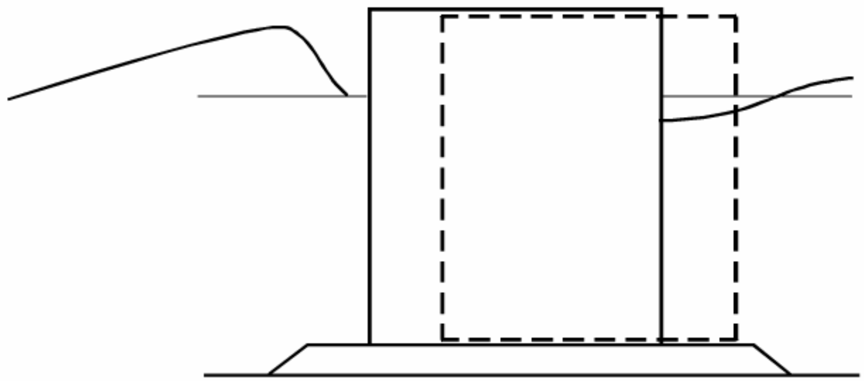
Modes of Failure

The following examples outline modes of failure for Timber Crib Structures. Included in the Coastal Engineering Manual for Caissons,

http://users.coastal.ufl.edu/~sheppard/eoc6430/Coastal_Engineering_Manual.htm

Both structures encounter the same structural concerns...

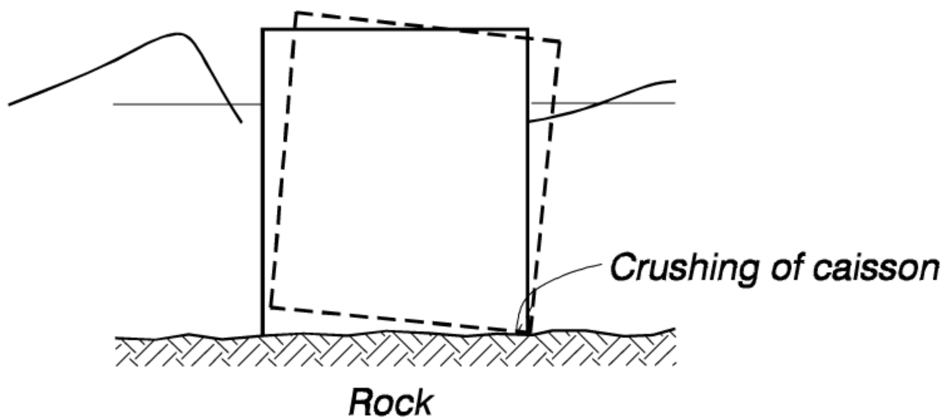
Sliding



Shoreward sliding of caisson

- *Resulting horizontal wave force in seaward direction exceeds the friction force between the caisson base plate and the bedding layer.*
  Large resulting shoreward wave force occurs when wave crests hit the caisson front simultaneously with wave troughs at the rear of the caisson.

Overturning

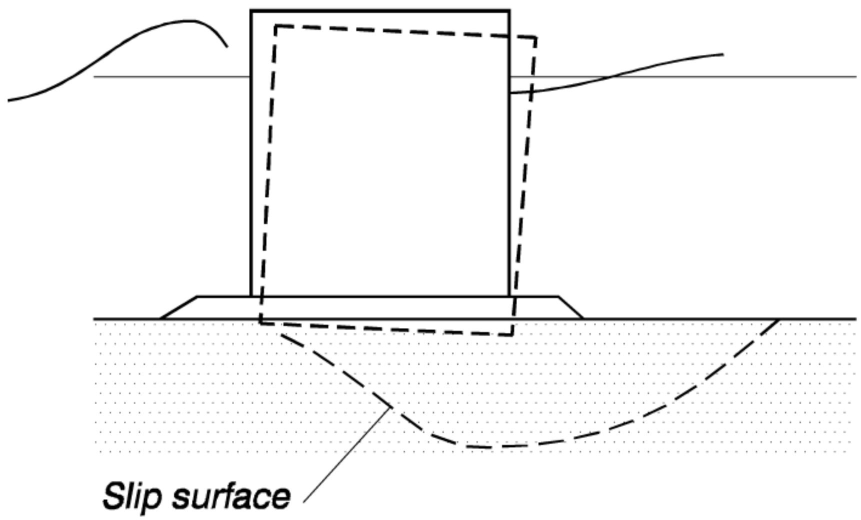


Overturning of caisson around heel

- *Tilting of the caisson takes place when the wave-induced resulting moment exceeds the gravity-based stabilizing moments.*
  The failure mode is relevant only to cases where ground failure does not occur, i.e., in case of rocky seabeds and very strong subsoils.
  Tilting of a caisson will in most cases cause local crushing of the caisson heel and cracking in the caisson walls.

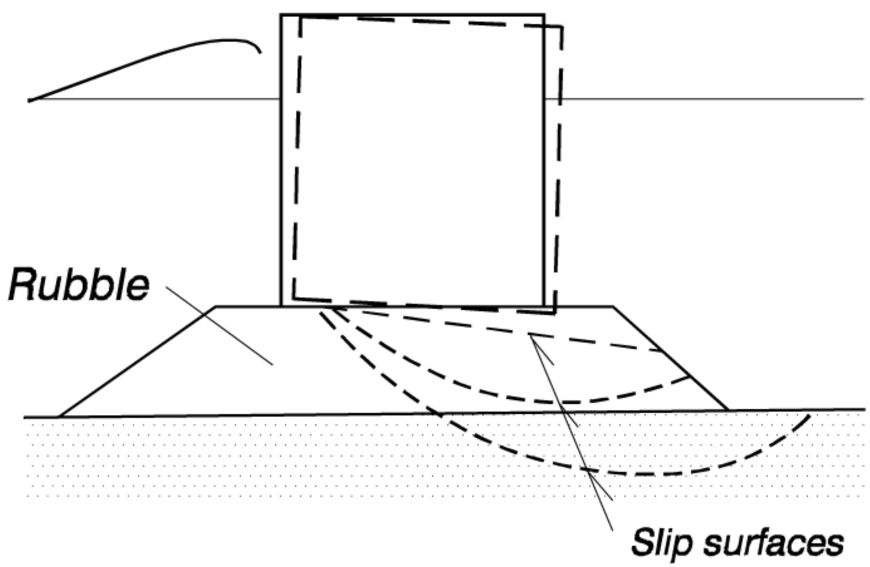
Solutions

- Concrete ballasting
- Increase crib size (more ballast)
- Breakwater protection



Slip failure in subsoil

- The caisson base plate load on the subsoil creates stresses **that** exceed the strength of the soil.
  The strength of the soil is influenced by possible pore pressure built up due to the cyclic wave-induced pressure variations in the soil.
- The slip surface failure causes the caisson to rotate and settle.

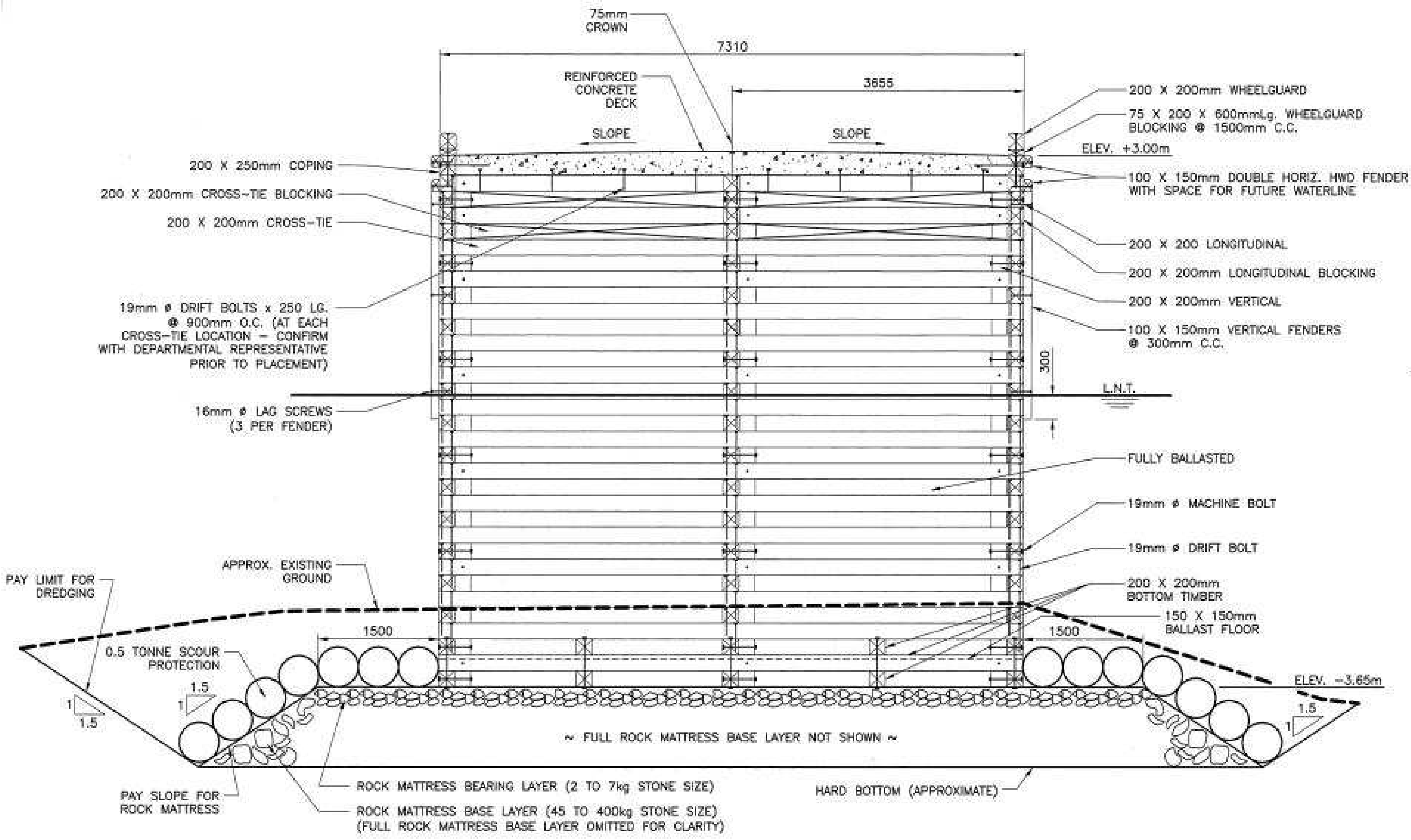


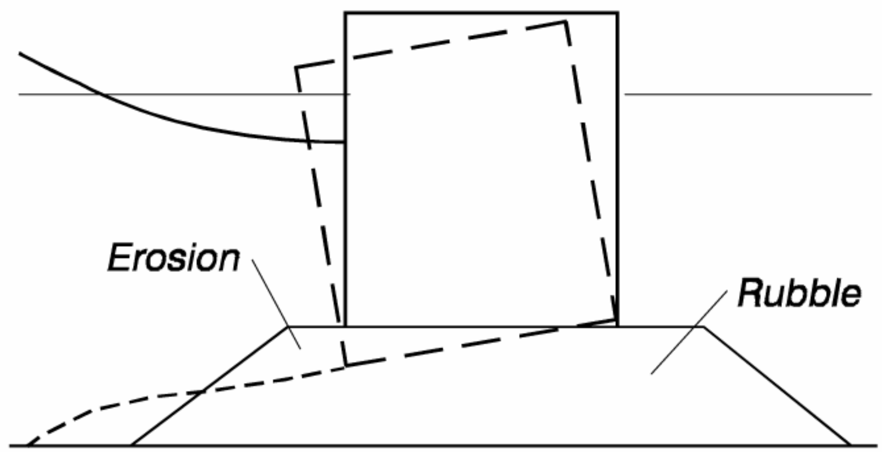
Slip failures in rubble foundation and subsoil

- *The caisson base plate load on the rubble foundation creates stresses **that** exceed the strength of the rubble material and possibly also that of the subsoil. Subsoil strength might be influenced by wave-induced pore pressure buildup.*

- Review Specs for Rock Mattress
- Remove unsuitable material (Dredge)
- Geotechnical Investigation

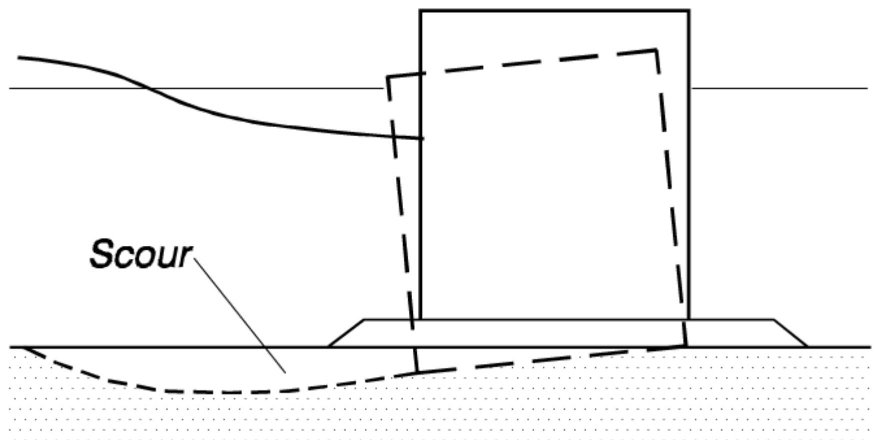
Crib Construction – Cross Section





Erosion of rubble foundation, seaward tilt,and settlement

- *Wave-induced erosion of the seaward rubble foundation might cause seaward tilt and subsequent settlement of the caisson.*
- *Critical wave load situations exist when deep wave troughs occur at the caisson front.*



Scour in seabed, seaward tilt,and settlement

- *Scour in front of a caisson due to waves and currents might cause seaward tilt and settlement of the caisson.*
- *Critical wave load situations exist when deep troughs occur at the caisson front.*

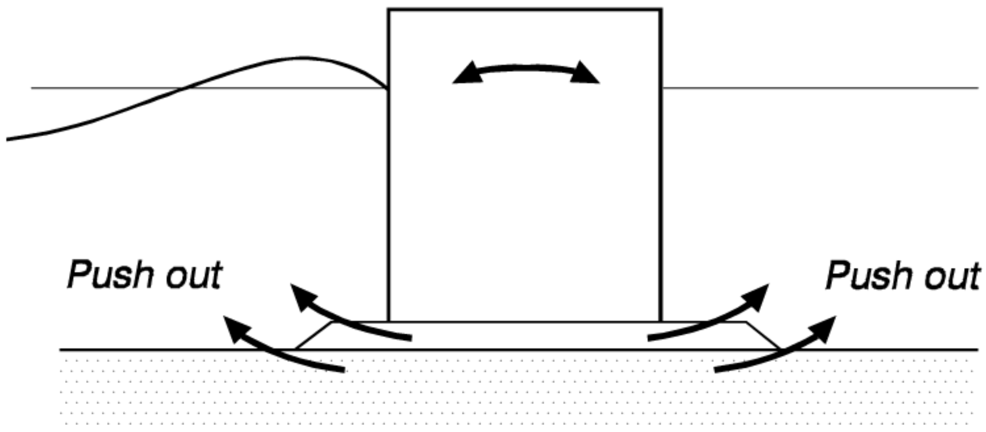
St. Shott's, 1989

St. Shott’s, New Breakwater Design

- Site excavated to bedrock
- 12” pipe drilled, anchored to seafloor through crib structure
- Reinforcing steel tensioned
- Concrete filled cribs
- Concrete seawall installed

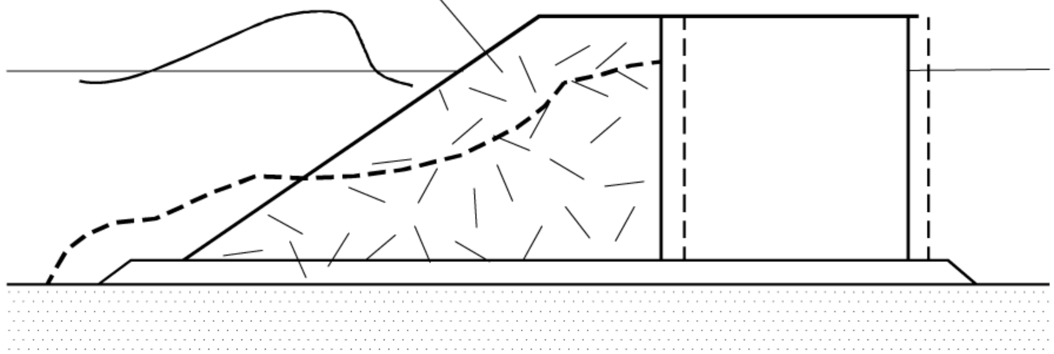
St. Shott's, 1991

Portugal Cove South – Crib Seating Erosion



Pushout of base material due to rocking motion of the caisson

- *Wave-induced rocking motion of a caisson causes oscillatory porous flow in the bedding layer and the subsoil.*
- *In case of relatively fine materials, a push out of material might take place resulting in increased rocking motion and subsequent possible ground failure and tilt of the caisson.*

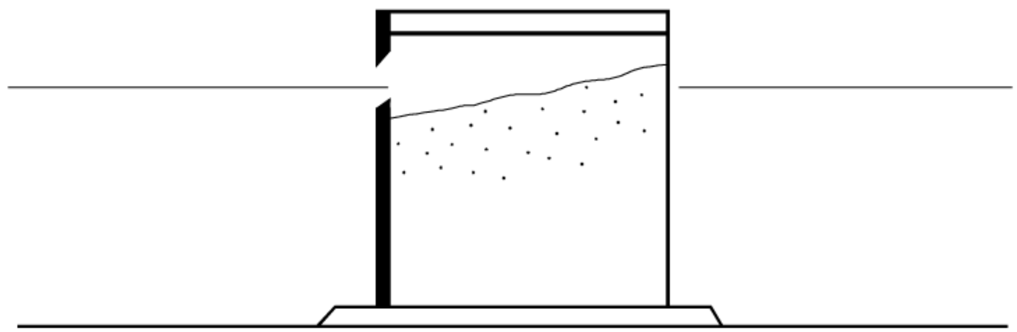


Breakage and displacement of armor units in front of caisson

- *Wave action might lead to breakage and/or displacement of the armor units.*
- *The subsequent increase in the wave forces on the caisson front wall might cause the caisson to slide.*
- *Damage to the armor protection might increase the overtopping.*

Flatrock, Newfoundland

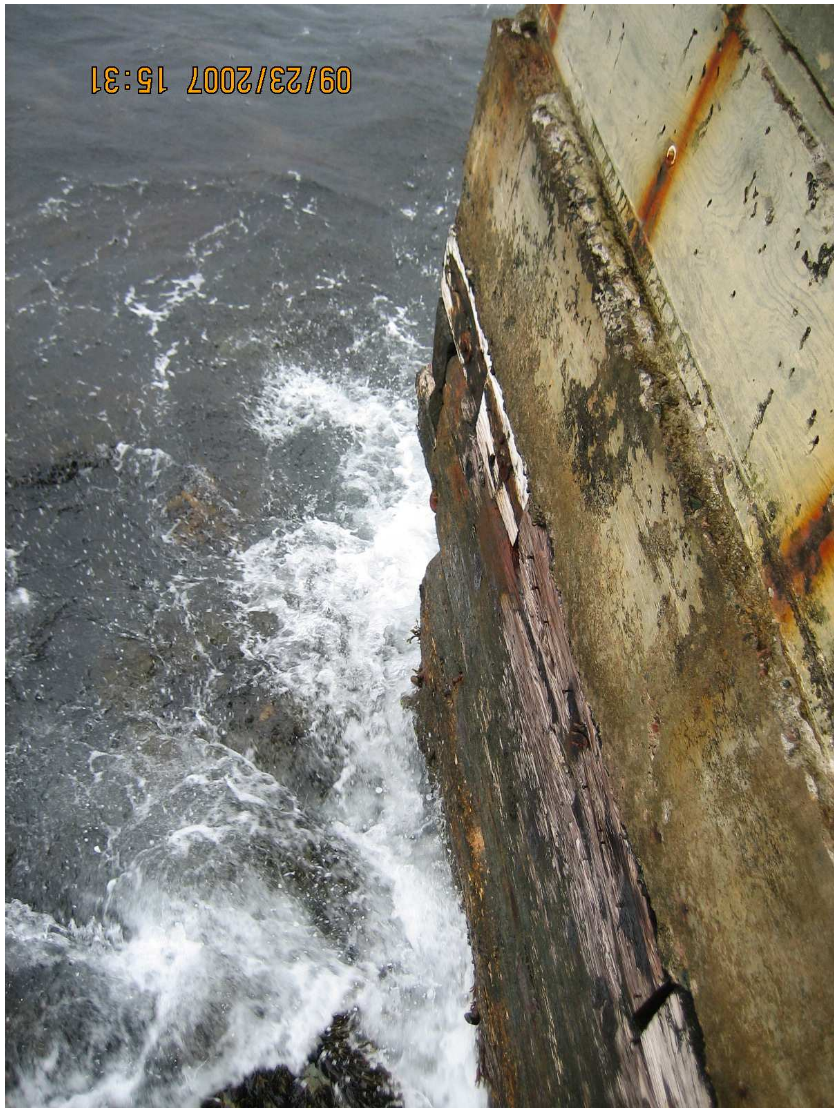
Flatrock, 2007



Failure of caisson front wall

- *Failures might be caused by excess wave loads, deteriorated reinforced concrete, and ship impact.*
- *If the caisson fill is leaking, the caisson might slide and/or tilt due to decreased gravitational stability.*

Portugal Cove South, 2007



Flatrock, 2008

Solutions - Open Faced Fendering

Solutions - Closed Face Fendering

Fenders

- Dissipate wave energy
- Protect crib structure from collision
  - Ice
  - Boats
- Help retain ballast

Wharf Structures

Bollard

Something Cool: Pumping Concrete, St. Shott’s, NL, 1991

(Note the crew working in top left picture)

Old Guy in Pick-up - St. Bride’s, February 3, 2007

(What you don’t see is the rifle laid across the passenger seat)