Rubble Mound Breakwater Design

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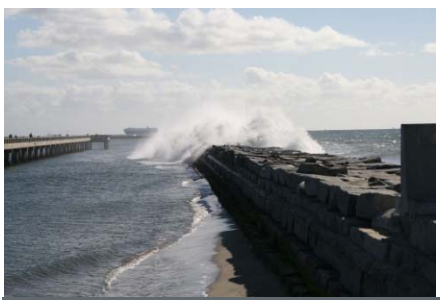

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Rubble Mound Breakwaters

- Consist of stone or other material dumped in place
- Relatively inexpensive and useful
- **<u>Purpose:</u>**
  To protect coastal areas from high intensity wave action

Breakwater near ferry entrance of Port aux Basques, NL

Breakwater Design

- Hudson Formula:

$$W = \frac{\gamma_a H^3}{K_D (S_a - 1)^3 \cot \alpha}$$

- Where:

Symbol	Meaning	Units
W	Weight of individual stone	N
Gamma (a)	Specific weight of stone	N/m^3
H	Wave height	m
K(d)	Stone shape coefficient	
S(a)	Specific gravity of stone	
Alpha	Slope angle of breakwater	degrees

Design Facts

- Designed with layers of different size stones
- One or two exterior layers of large armor units
- Units may be stone or concrete
- Weight of armor stone must be able to resist wave forces
- Cannot be all armor stone due to high porosity
  (plus the price)

Important Considerations

- **Wave height**
  - ❖Significant wave height versus H10 wave height (recommended)
- **Breaking or non-breaking**
  - ❖Does it break on the structure or is overtopping permitted
- **Stability**
  - ❖Interlocking blocks provide more stability (tribar, dolos or tetrapods)
  - ❖Cost considerations?

Important Considerations

- **Slope**
  - ❖Flatter slopes increase stability
  - ❖Flatter slopes increase size and cost
- **Number of Layers**
  - ❖Typically use two
- **Must evaluate risk versus cost – Key engineering decision!**

Quarry Stone

Tetrapods

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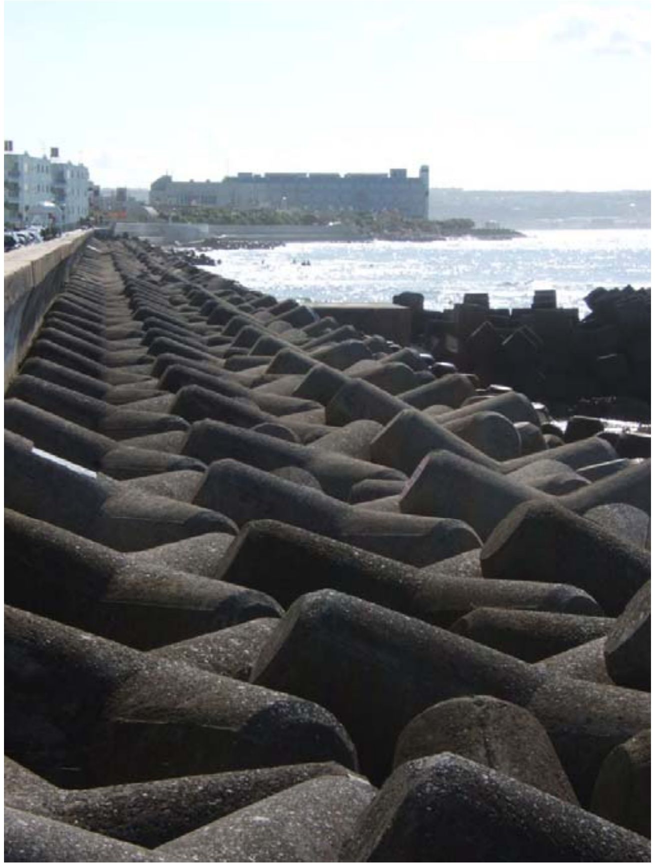


Tribar

Dolos

Breakwater Design – Profile

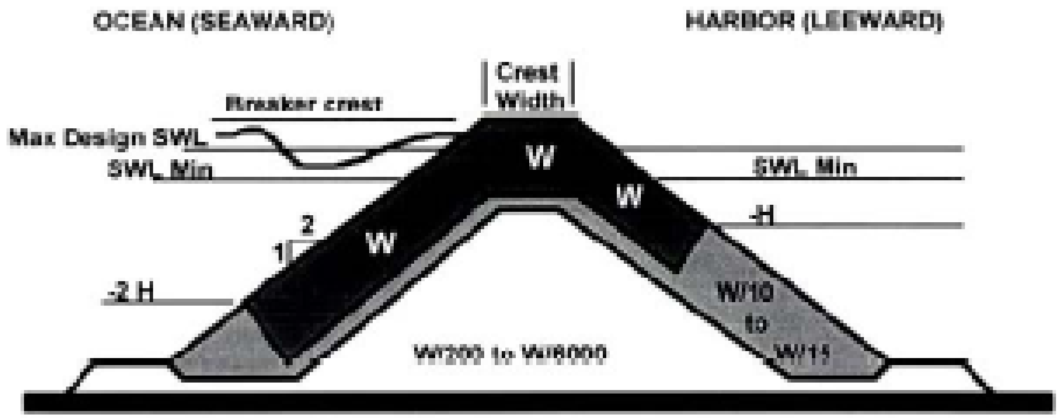


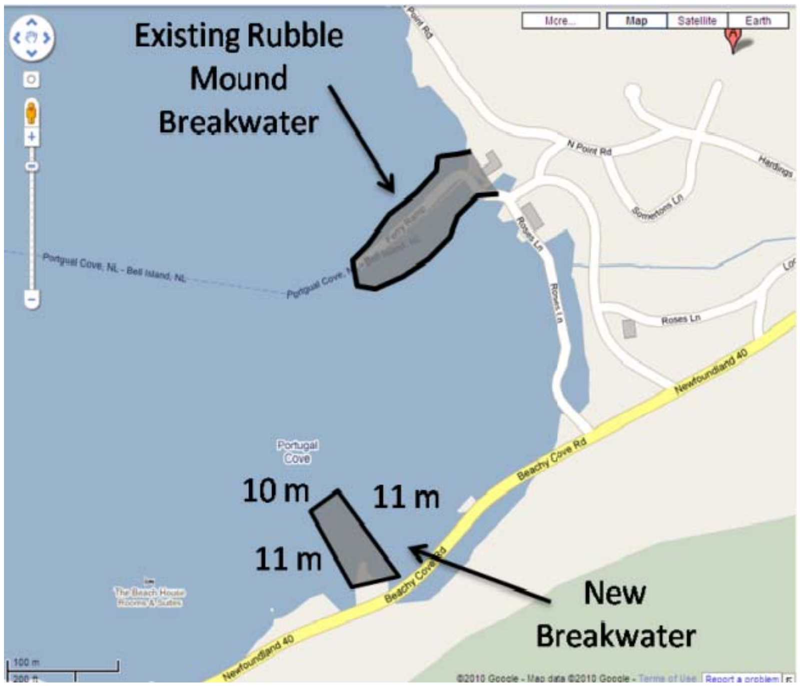
Figure 4-21. Sketch of common breakwater rubble mound structure where W is weight of armor unit.

Breakwater Design – Key Table

Armor Unit	Number of Armor Unit Layers	Placement Technique	Trunk Structure		Head Structure		Slope
			K_D		K_D		
			Breaking Wave	Non Breaking Wave	Breaking Wave	Non Breaking Wave	Cot α
Quarrystone (smooth rounded)	2	random	1.2	2.4	1.1	1.9	1.5 to 3.0
Quarrystone (rough angular	1	random	Non recommended	2.9	Not recommended	2.3	1.5 to 3.0
Quarrystone (rough angular	2	random	2.0	4.0	1.9 1.6 1.3	3.2 2.8 2.3	1.5 2.0 3.0
Quarrystone (graded angular)		random	2.2	2.5			
Tetrapod	2	random	7.0	8.0	5.0 4.5 3.5	6.0 5.5 4.0	1.5 2.0 3.0
Tribar	2	random	9.0	10.0	8.3 7.8 6.0	9.0 8.5 6.5	1.5 2.0 3.0
Tribar	1	uniform	12.0	15.0	7.5	9.5	1.5 to 3.0
Dolos	2	random	15.8	31.8	8.0	16.0	2.0

Note: K_D values are for no damage and minor overtopping.

Breakwater Design – Example C7



- If a second breakwater were planned for Portugal Cove in water depths as shown below but for significant wave heights of only **3.0 m** (no breaking), what kind of armor unit would you use and why?

- If you were to design concrete Dolos for this application determine the weight of each unit if the specific weight of reinforced concrete is 3.3.

Example C7 - Solution

Part 1:

- Use the same kind of stone as the first breakwater
- Likely available, nearby and cheaper

Part 2:

- Instructed to use concrete dolos of specific weight 3.3
- Told this is a non-breaking wave
- First step→ Refer to table!

Example C7 - Solution

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Table 4-5. Suggested armor unit stability coefficients (K_D) for rubble mound structures (USACE 1984).

Armor Unit	Number of Armor Unit Layers	Placement Technique	Trunk Structure		Head Structure		Slope
			K_D		K_D		
			Breaking Wave	Non Breaking Wave	Breaking Wave	Non Breaking Wave	Cot α
Quarrystone (smooth rounded)	2	random	1.2	2.4	1.1	1.9	1.5 to 3.0
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Dolos	2	random	15.8	31.8	8.0	16.0	2.0

Note: K_D values are for no damage and minor overtopping.

Dolo Information	Value
Number of units	2
K(d) Head	16
K(d) Trunk	31.8
Cot (alpha)	2.0

Example C7 - Solution

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- Use the Hudson formula to determine the weight of the individual armor unit:

$$W = \frac{\gamma_a H^3}{K_D (S_a - 1)^3 \cot\alpha}$$

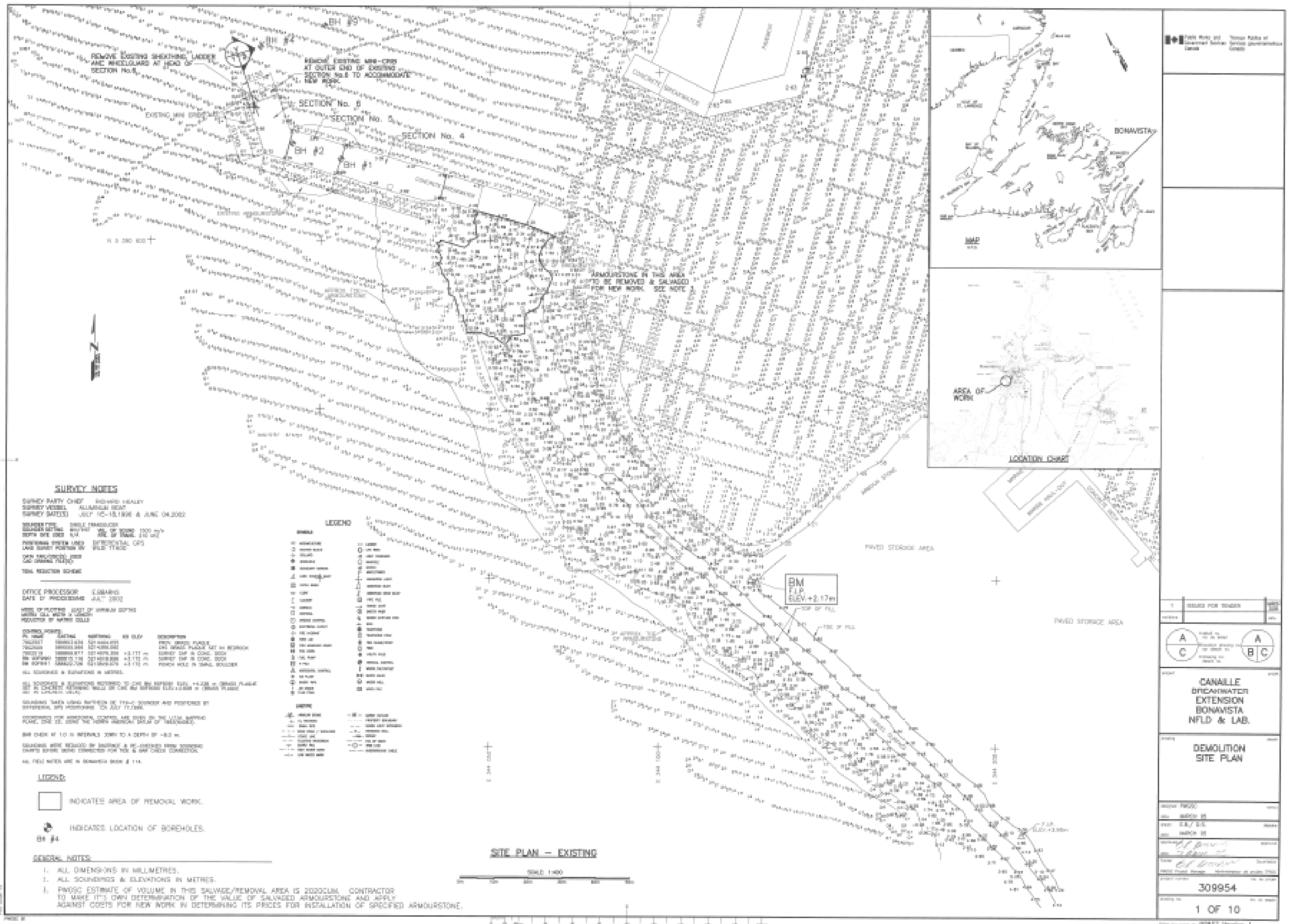
$$W = \frac{3.3 \times 1000 \frac{kg}{m^3} \times 9.81 \frac{m}{s^w} \times (3m)^3}{16(3.3-1)^3 \times 2}$$

$$W = \frac{32373 \frac{N}{m^3} \times 27\ m^3}{389}$$

$$W = 2247\ N = 229\ kg$$

- Number is small due to high stone shape coeff for dolos

Real Breakwater Design - Bonavista



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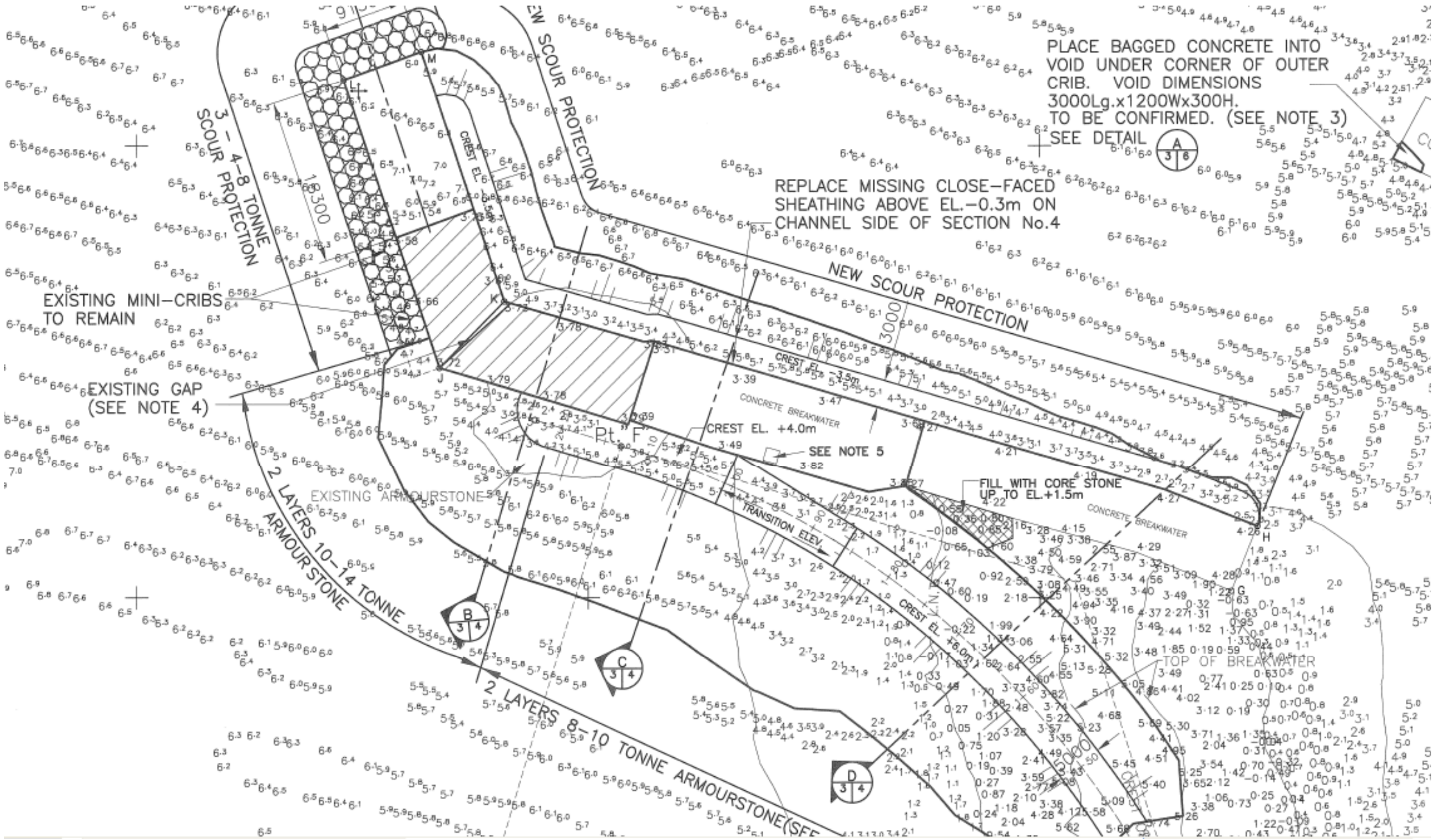
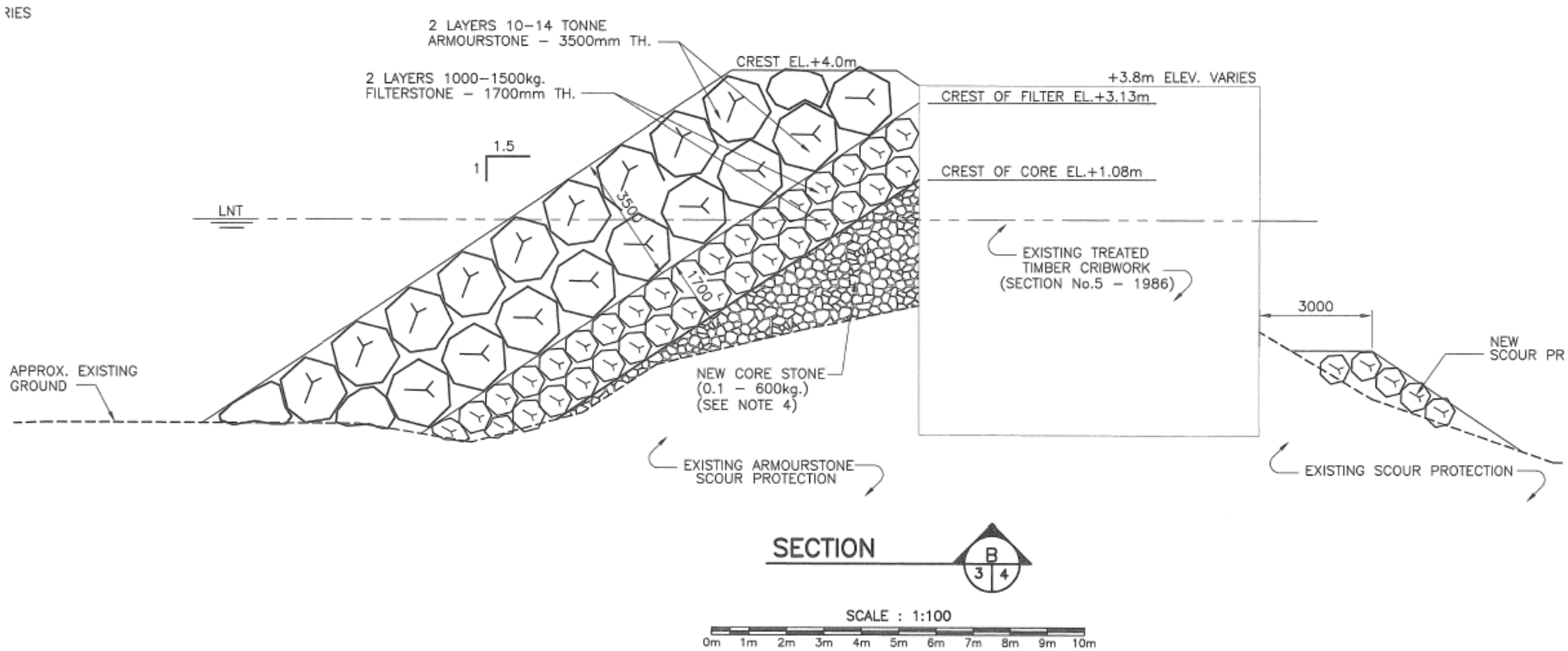


Real Breakwater Design - Bonavista



- We know: slope, number of layers, weight, stone type
- Can we determine the design wave height?

Real Breakwater Design - Bonavista

$$S_a\ granite = 2.7$$

$$W = 14\ tonne = 14\ 000\ kg = 137\ 340\ N$$

$$cot\alpha = \frac{1}{tan\alpha} = \frac{1.5}{1} = 1.5$$

Assuming rough angular quarry stone, 2 layers, and breaking waves:

$$K_D = 1.9$$

Therefore:

$$W = \frac{\gamma_a H^3}{K_D (S_a - 1)^3 cot\alpha}$$

$$137\ 340\ N = \frac{2.7 \times \frac{1000kg}{m^3} \times 9.81\frac{m}{s^2} \times H^3}{1.9(2.7-1)^3 \times 1.5}$$

$$H = 4.15\ m$$