Xbloc & XblocPlus

Efficient Wave Protection: Resilient – Sustainable – Economical

Pieter Bakker - Delta Marine Consultants

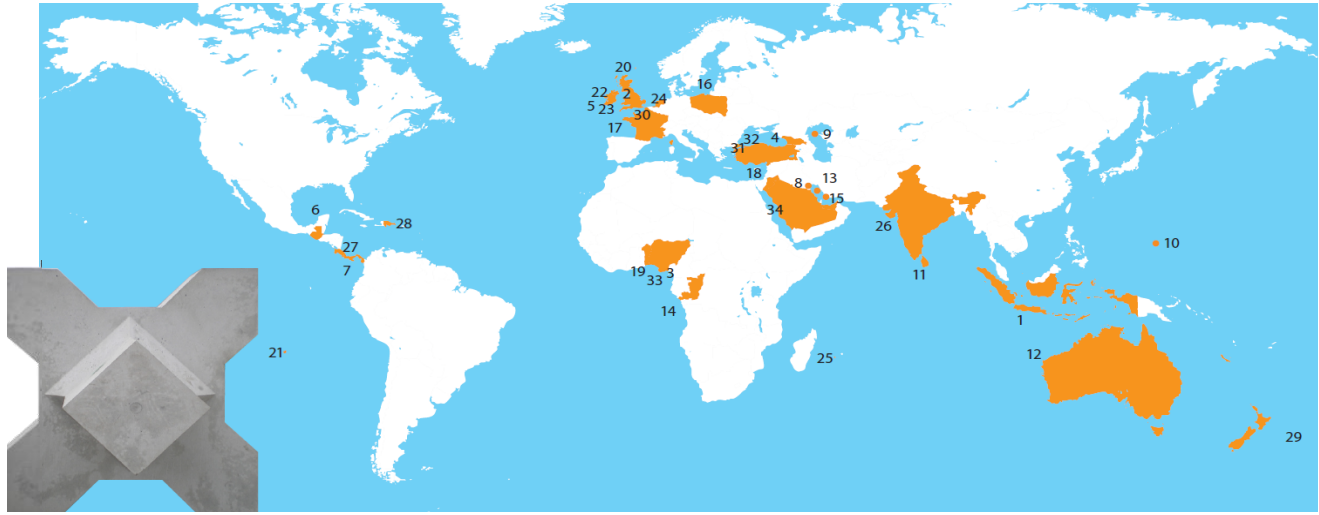
Xbloc Armour Units

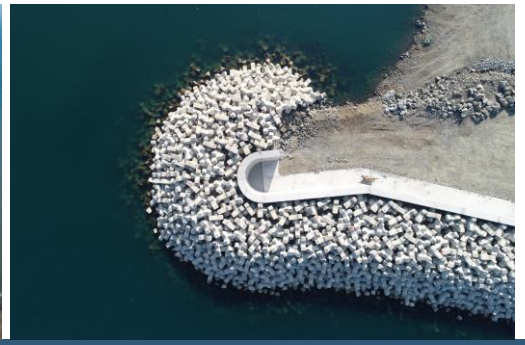
Single Layer; unreinforced concrete

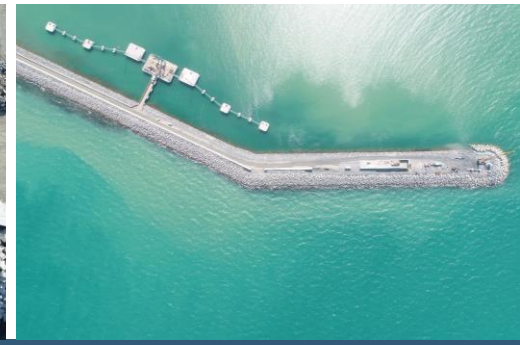
Applied Worldwide Since 2003

More than 600,000 Xblocs placed

Sizes from 2 to 43 ton







Xbloc

XblocPlus

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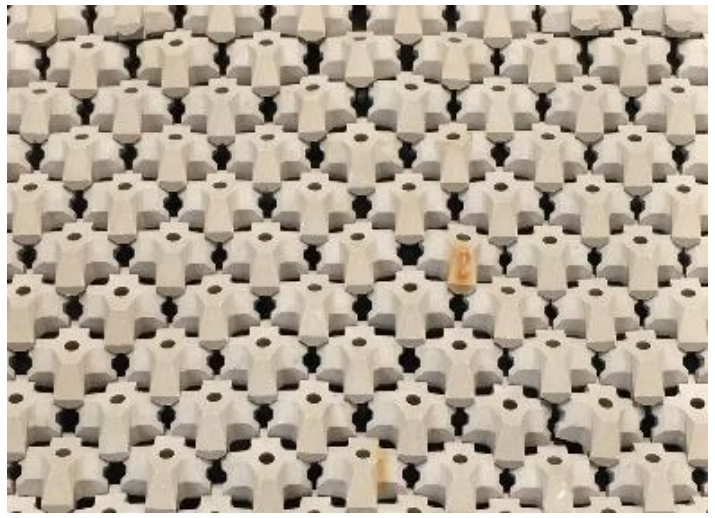
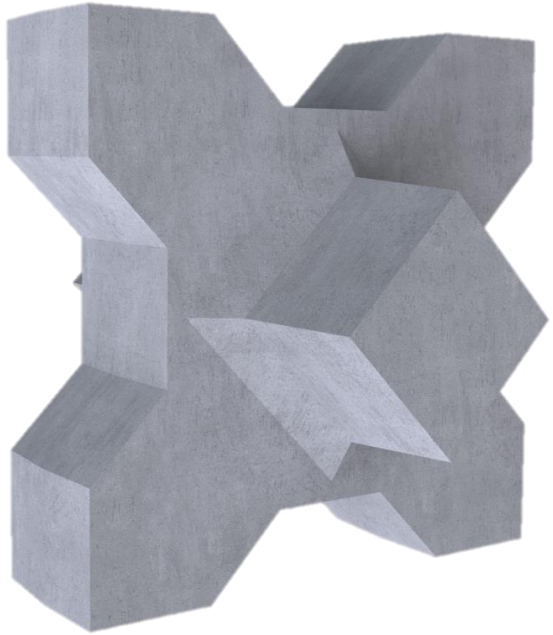
Trigger XblocPlus Development: Regular Placement

Xbloc random placement:
Good packing density

Xbloc regular placement:
Higher packing density
Faster placement (no thinking)
Incorrect, but frequently seen in projects

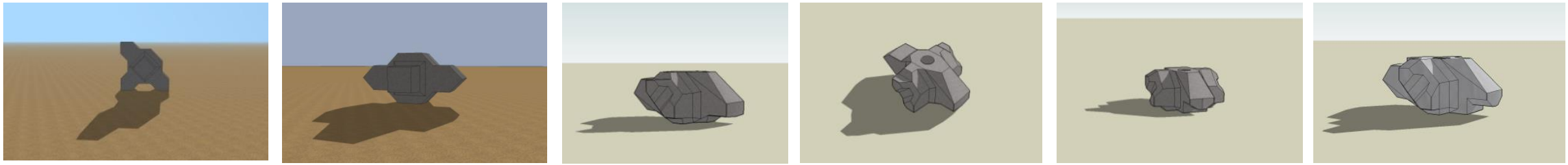


XblocPlus objective:
Regular placement
Faster placement



Xbloc

XblocPlus



2015 | 2016 | 2017

XblocPlus Projects

Afsluitdijk – The Netherlands (completed)
75,000 blocks of 2.5m3

Vistula Spit – Poland (completed)
10,000 blocks of 1m3, 3m3 and 4m3

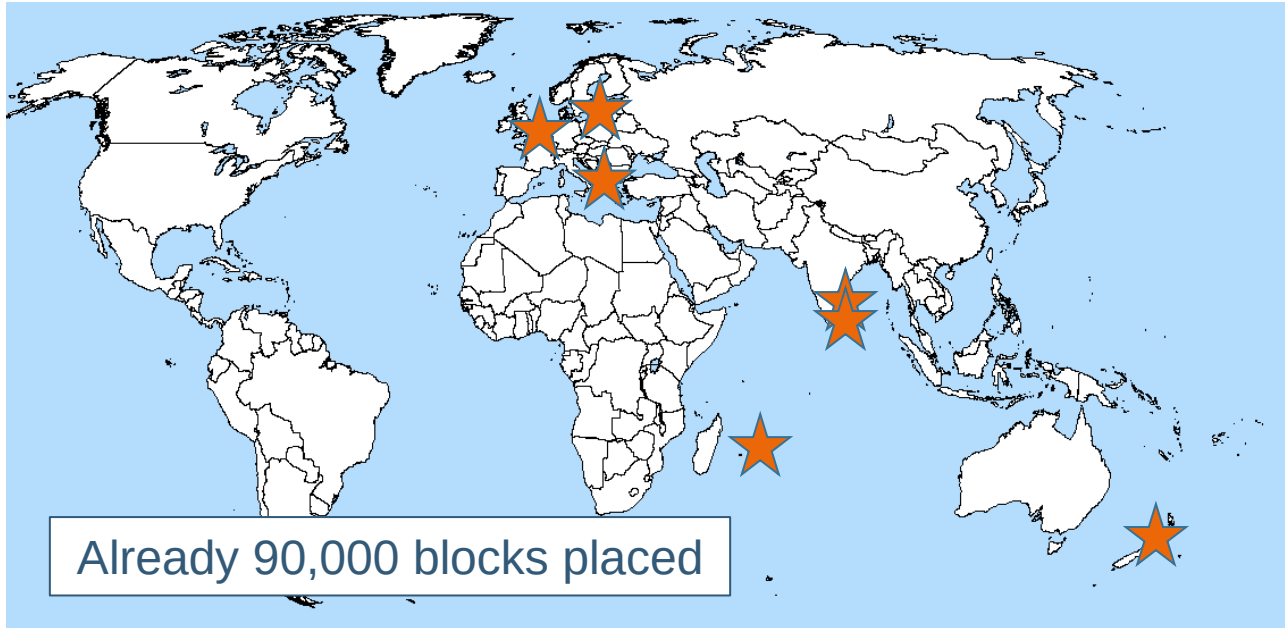
La Reunion Airport – La Reunion (under construction)
10,000 blocks of 2m3

Porto Albania – Albania (design completed)
4,000 blocks of 4m3

Ramayapatnam – India (design ongoing)
25,000 blocks of 6m3

Kakinada Gateway Port – India (design ongoing)
20,000 blocks of 1.5, 2 ,4 and 5m3

Te Ara Tupua – New Zealand (design ongoing)
7,000 blocks of 1m3



Why XblocPlus?

Resilience to climate change	Safety against more severe storms
Most economical	Reduced material quantities & 30% - 50% fewer blocks
Most ecological	Increased biodiversity
Minimum Carbon Footprint	Relative to other hard structures (concrete and rock)
Aesthetics	Smooth, architectural finish - Ideal for marinas and shore protections in urban environments

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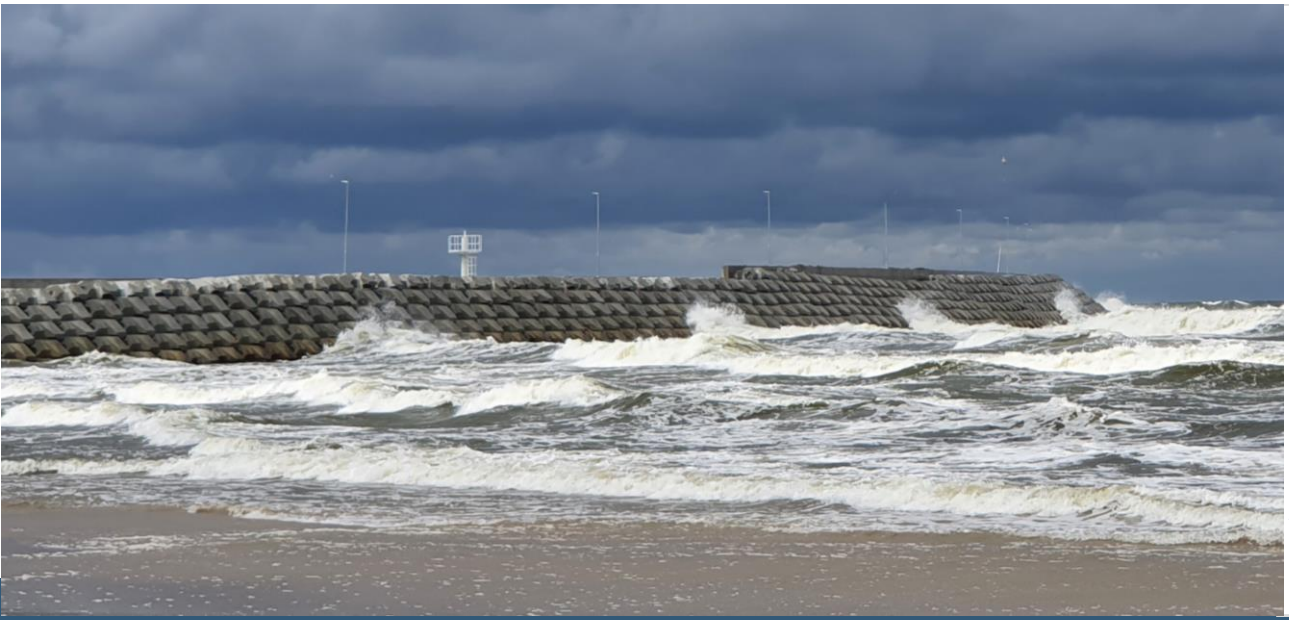
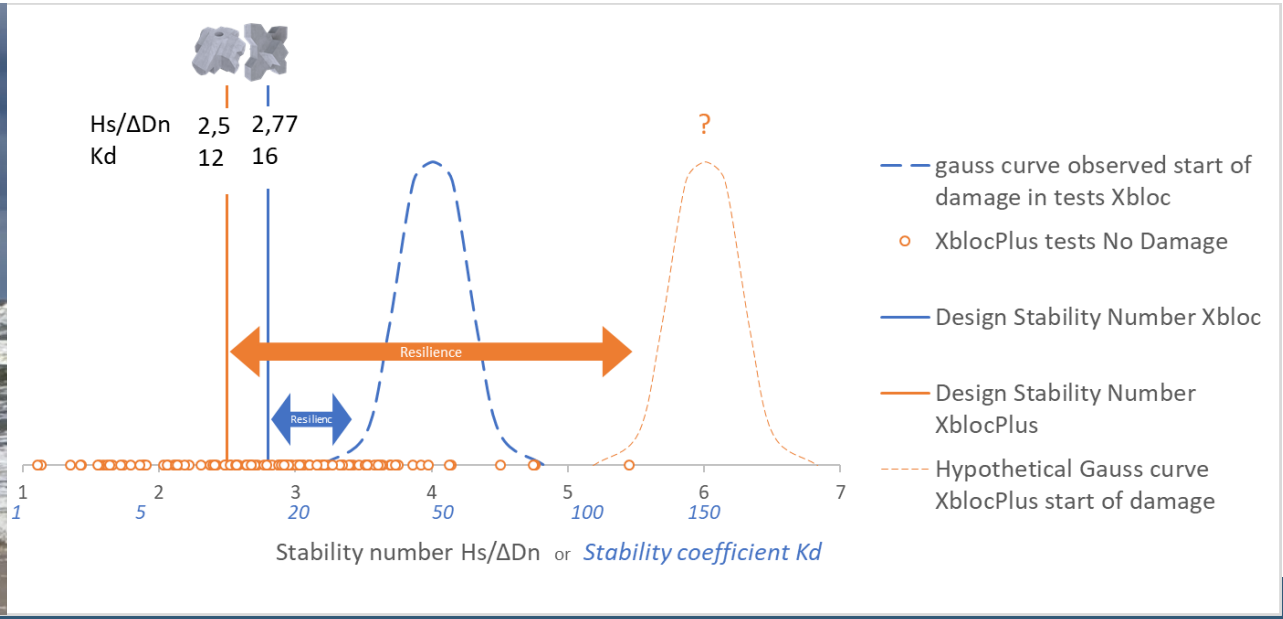
Reliability & Resilience for Climate Change

Structures designed for 30 up to 100 years; which design wave height to use?

Resilience for higher wave heights

No damage even if waves are 2x higher than design wave

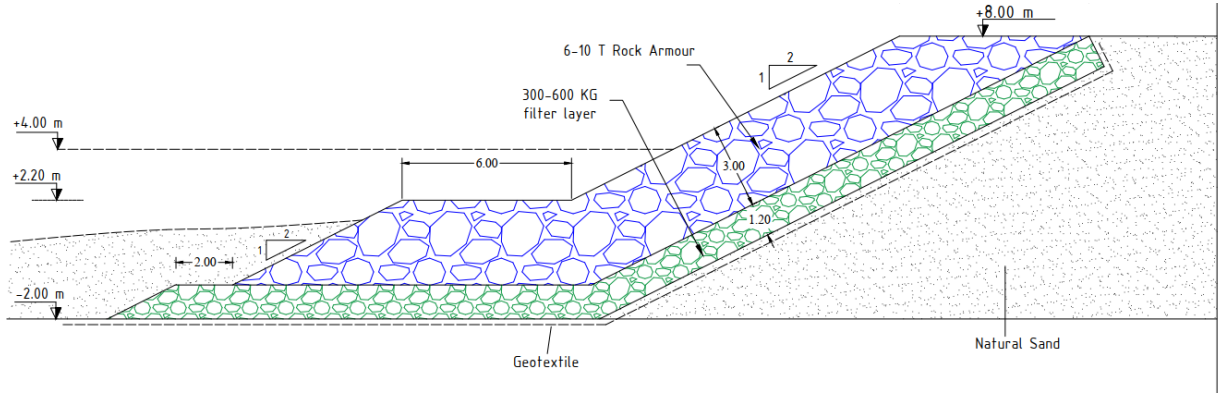


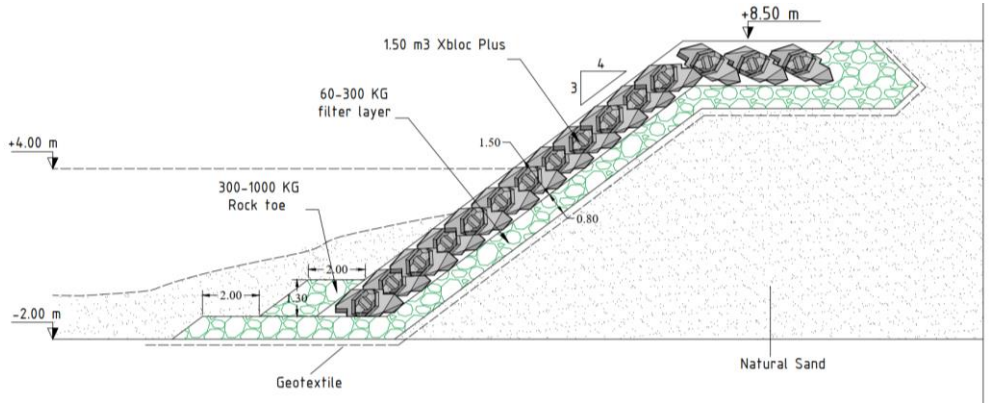


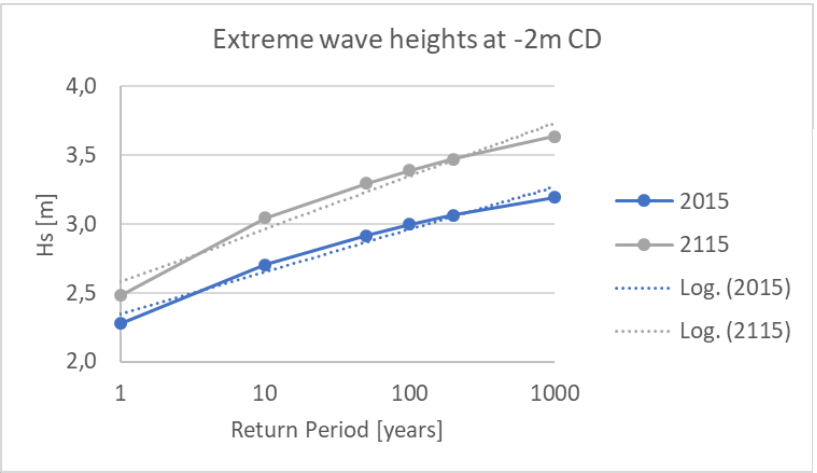
Maintenance Need

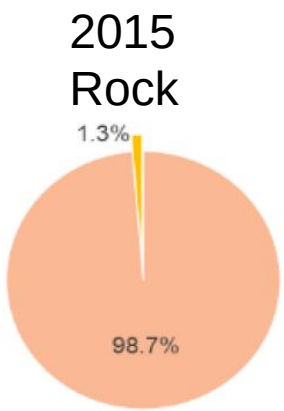
Example UK:

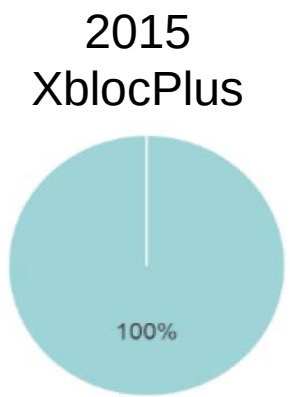
- Equivalent cross sections
- Life cycle analysis 50 years based on present and future wave climate
- Prediction of number of repairs needed

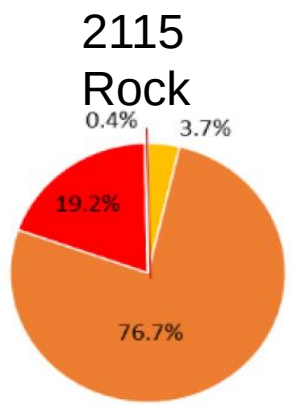


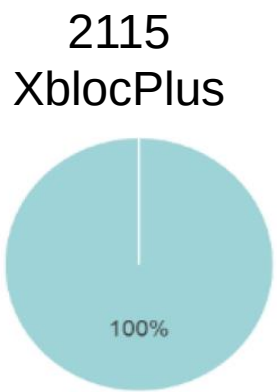








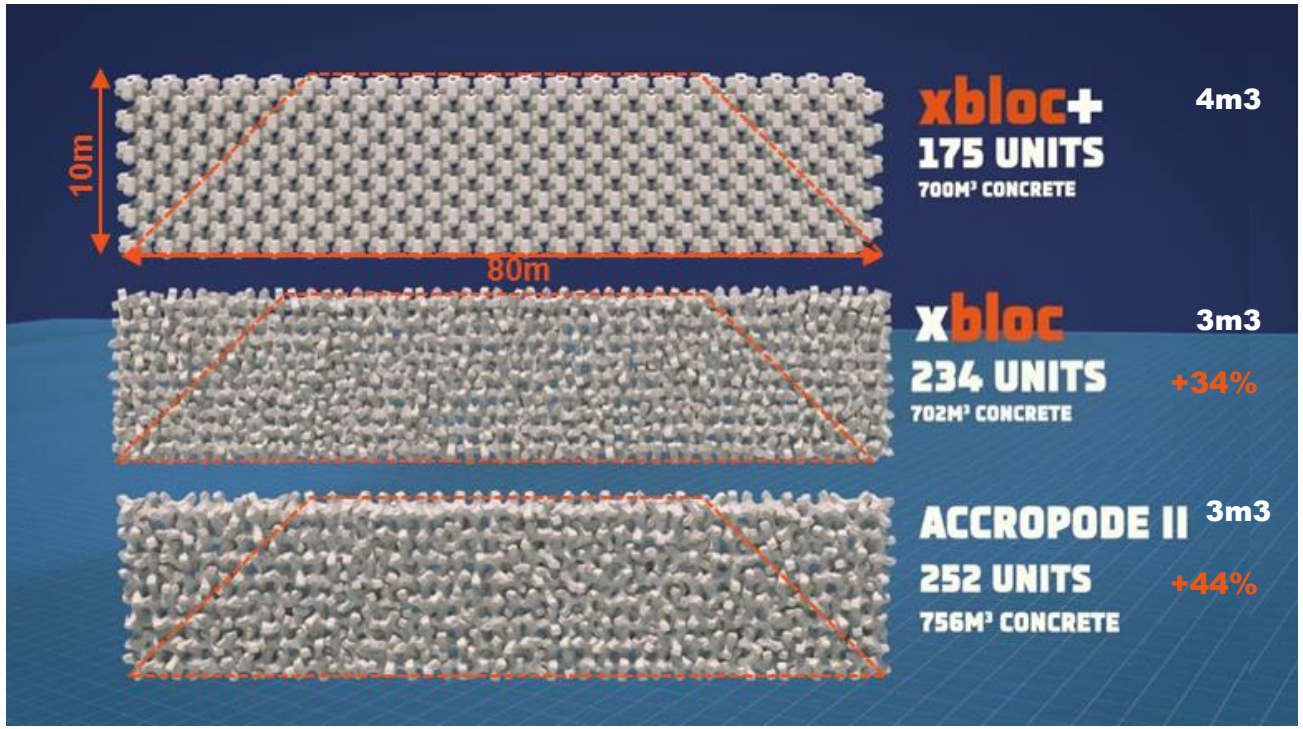




Most economical

Due to high resilience: larger XblocPlus

As a result: number of blocks needed reduced significantly



Xbloc

- Concrete use equal to XblocPlus
- 34% more blocks to cover same breakwater

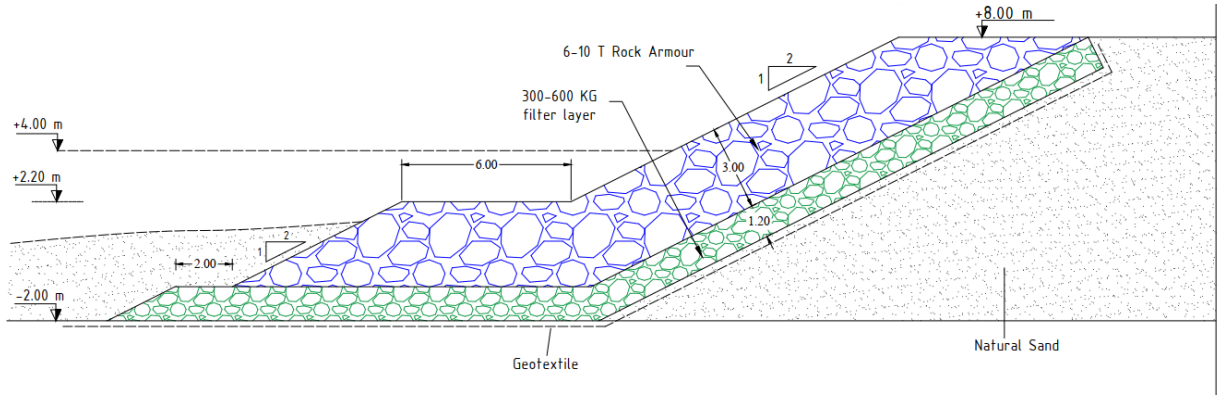
Accropode-II

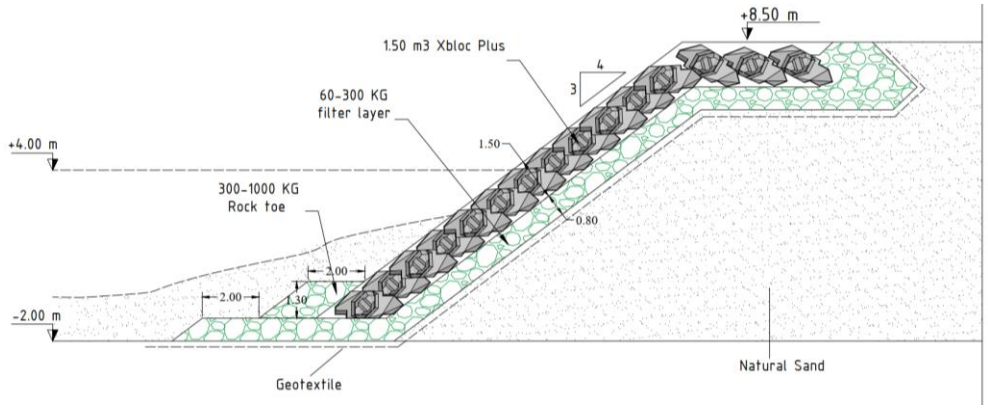
- 8% more concrete
- 44% more blocks to cover same breakwater

Consequences

- Reduced construction time
- Under layer exposure to waves during construction reduced

Economics





Compared to rock revetment:

- Steeper slope (hence wider beach)
- Less material
- Lower costs

Rock cross section: 190 ton/m (all rock gradings combined)

XbocPlus cross section: 67 ton/m (concrete + rock gradings)

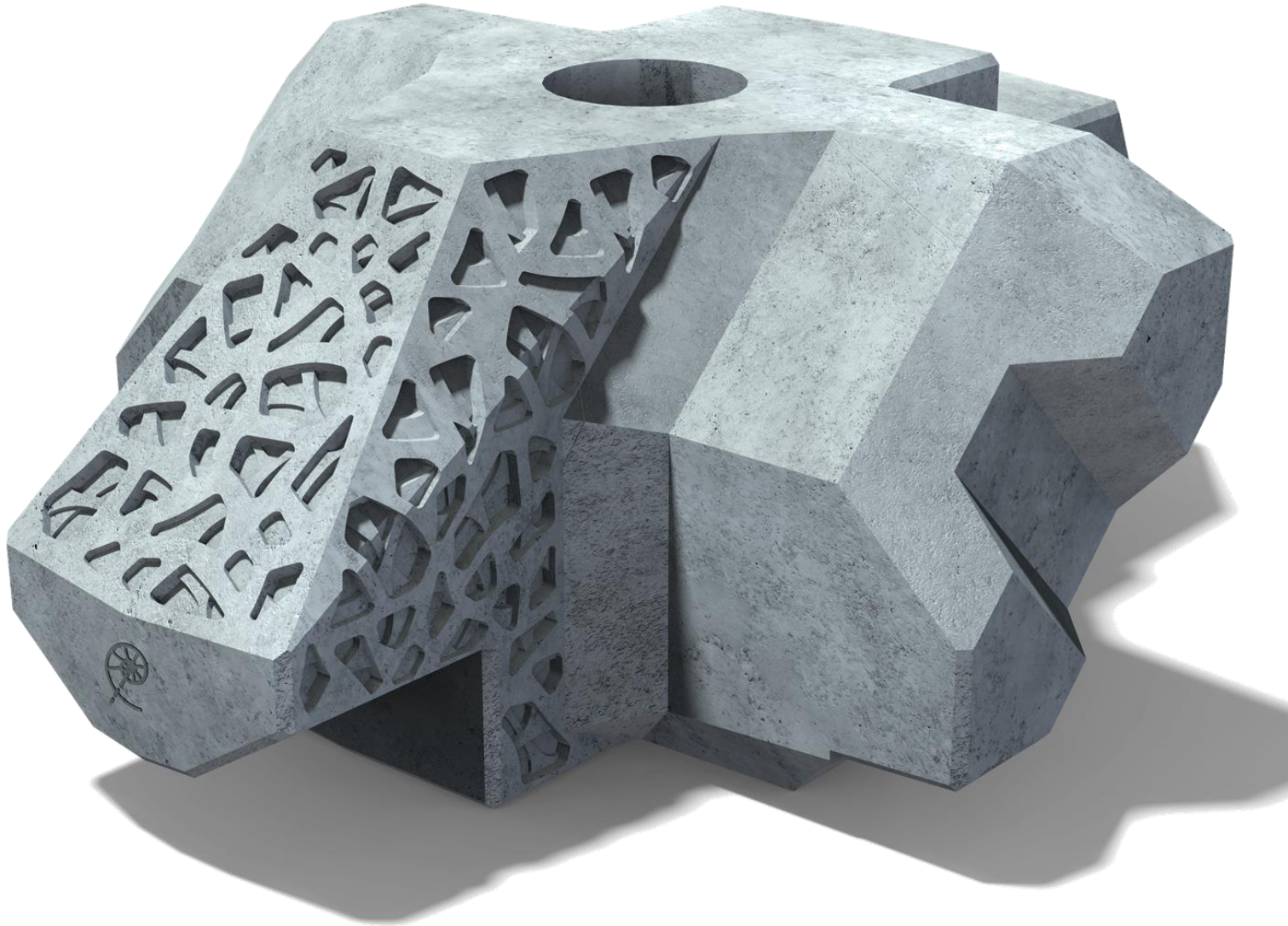
With tentative unit rates for UK projects:

Rock cross section 9,700€/m

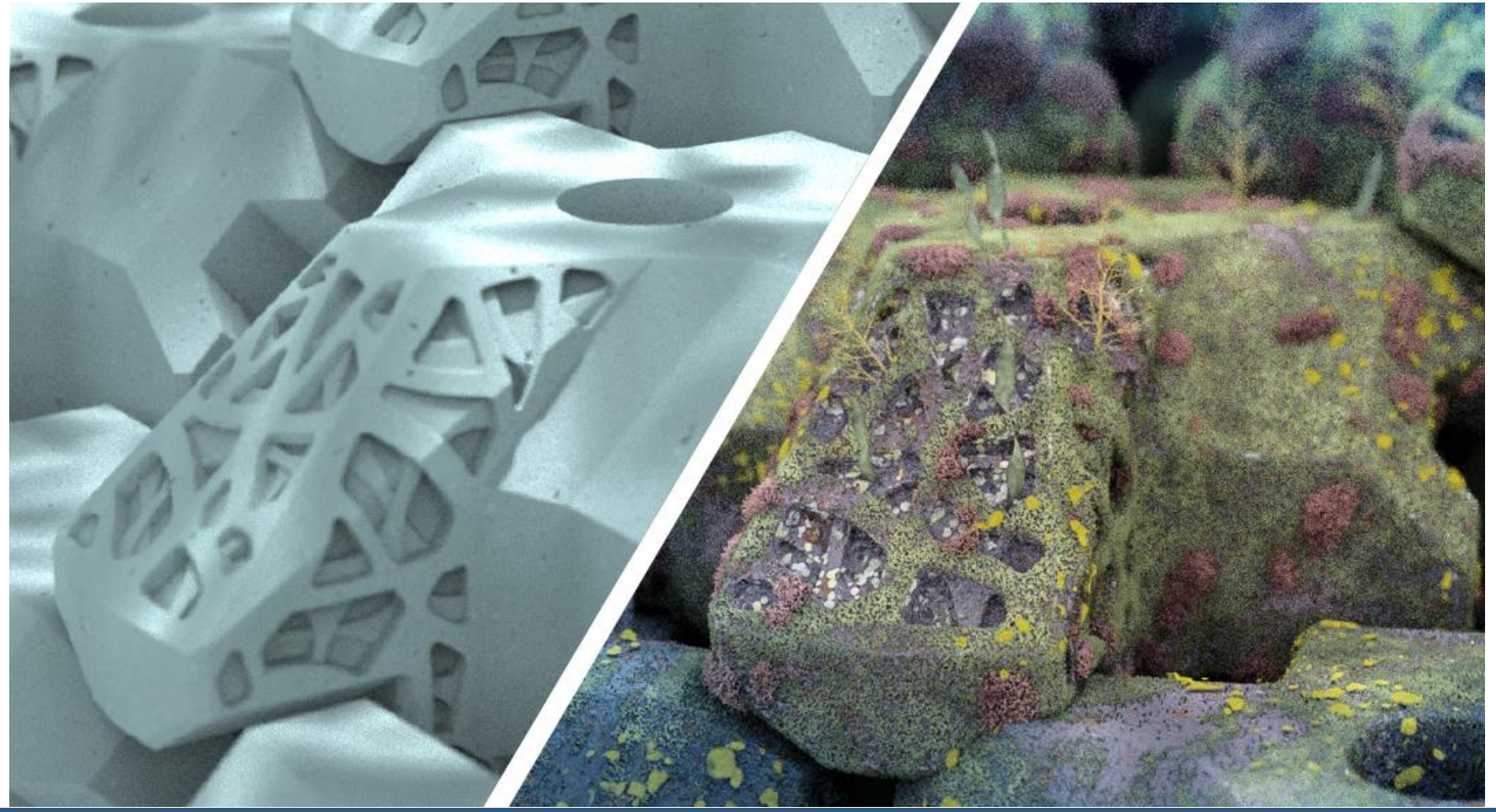
XblocPlus cross section 4,200€/m

Most ecological

- True sustainability and responsible construction
- Provide ecosystem services
- Increase biodiversity and carbon sequestration



Bio XblocPlus - How it works

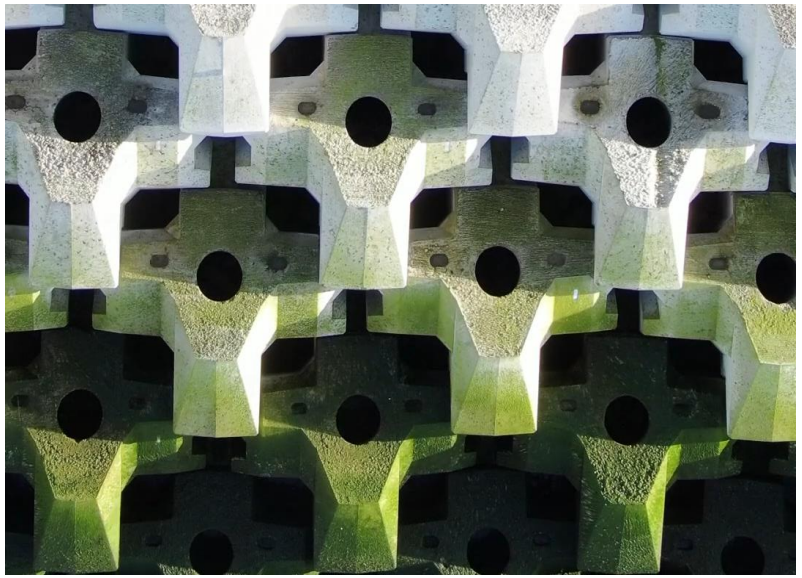


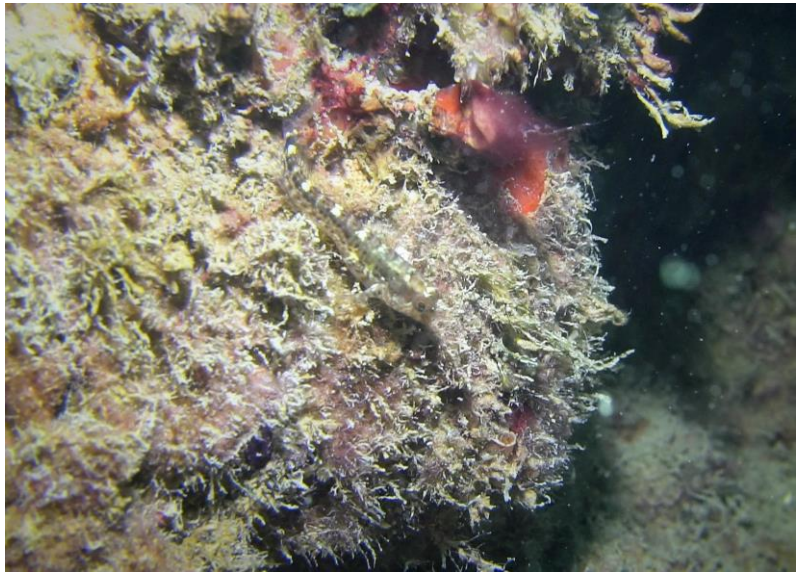
Chemical Composition


High Rugosity


Macro Design





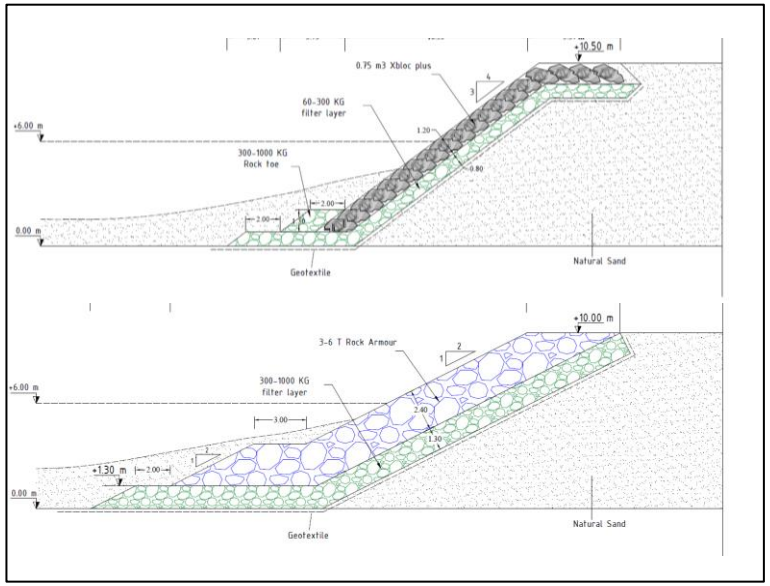



Sustainable: Material Quantities

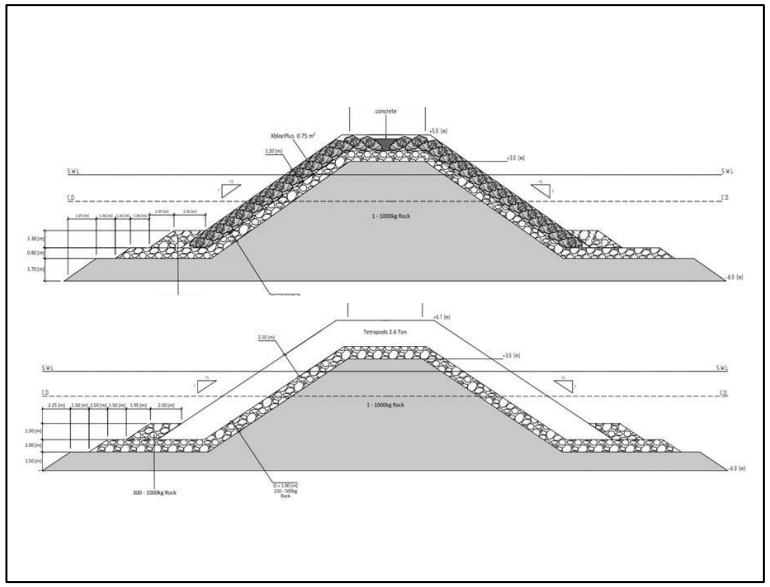
XblocPlus layer has 60% porosity → low material quantities

Low material quantities → reduced CO2 footprint

- Concrete blocks: less concrete and fewer blocks
- Rock armour: reduced material quantities
  transport of rock important parameter



- Shore protection example: 28% CO2 reduction on structure
- Breakwater example: 61% CO2 reduction on armour layer
- Afsluitdijk: 56% CO2 reduction on armour layer



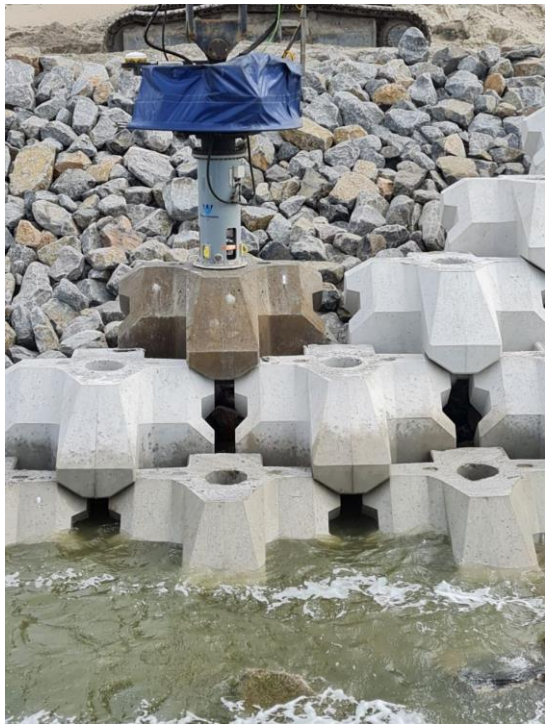
Blocks can be re-used after lifetime due to high stability

Sustainable: Material Composition

Many programs in the industry to reduce CO2 footprint of concrete and use circular materials

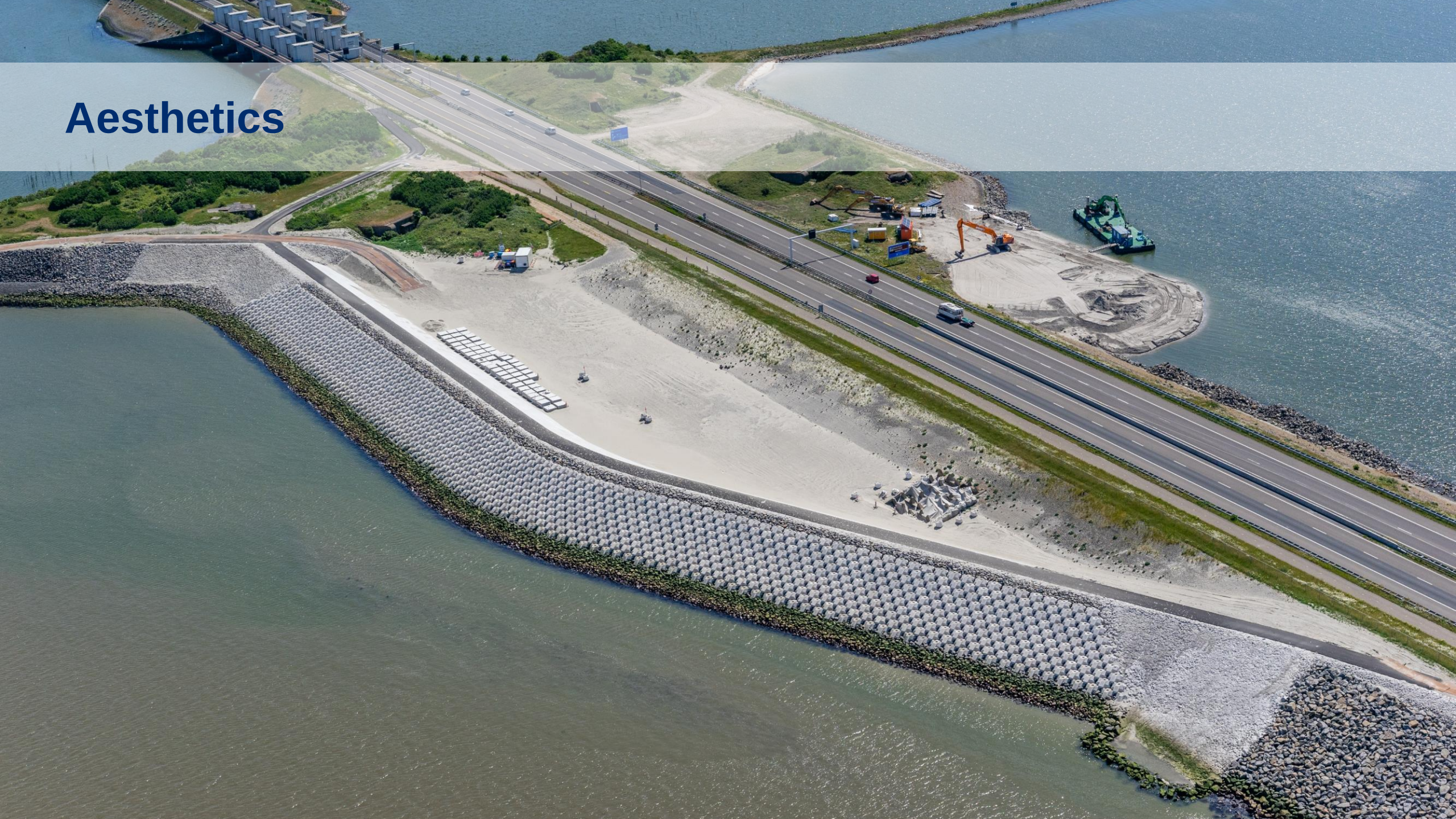
Proeftuin Afsluitdijk with Rijkswaterstaat

- 15 concrete mixes
- 2 blocks each
- 20 years monitoring



Cooperation of Rijkswaterstaat, Levvel, SGS, Smart Circulair Products, BTE Nederland B.V., HeidelbergCement, C2CA Technology B.V., Dyckerhoff Basal Betonmortel b.v., Sibelco Group, Mobilis TBI en BAM Infra Nederland.

Aesthetics



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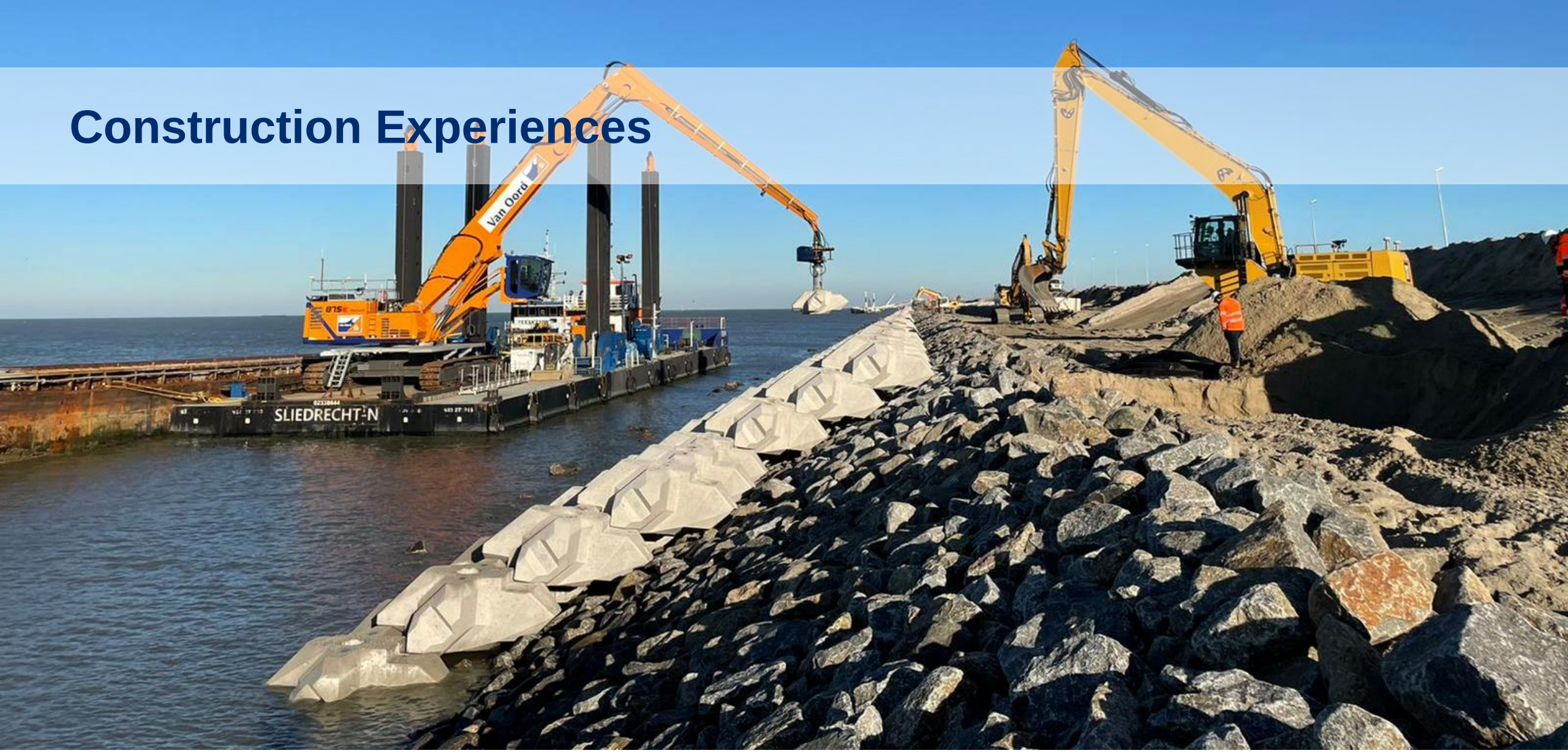
Stakeholder value XblocPlus

Designer:	safe design -> lower risk of claims
Contractor:	more economical
	fast & safe construction
Project Owner:	stronger structure for lower price
	resilient & adaptable to climate change
	less maintenance
Residents & recreationists:	aesthetics; biodiversity
Environment:	low carbon footprint
	stimulate biodiversity
	circularity

Construction Experiences



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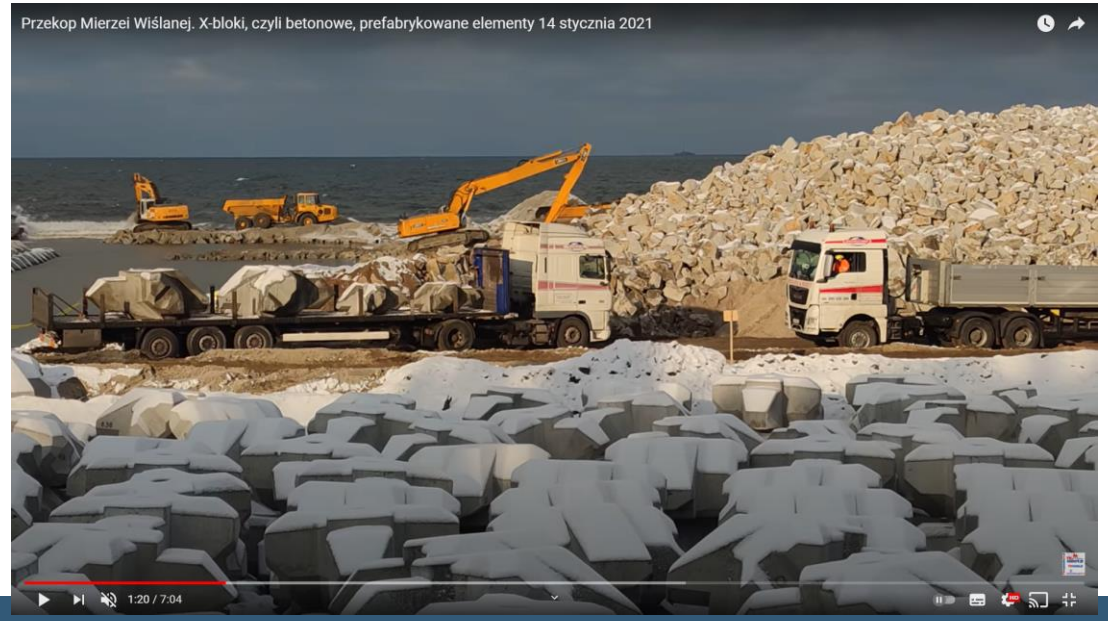

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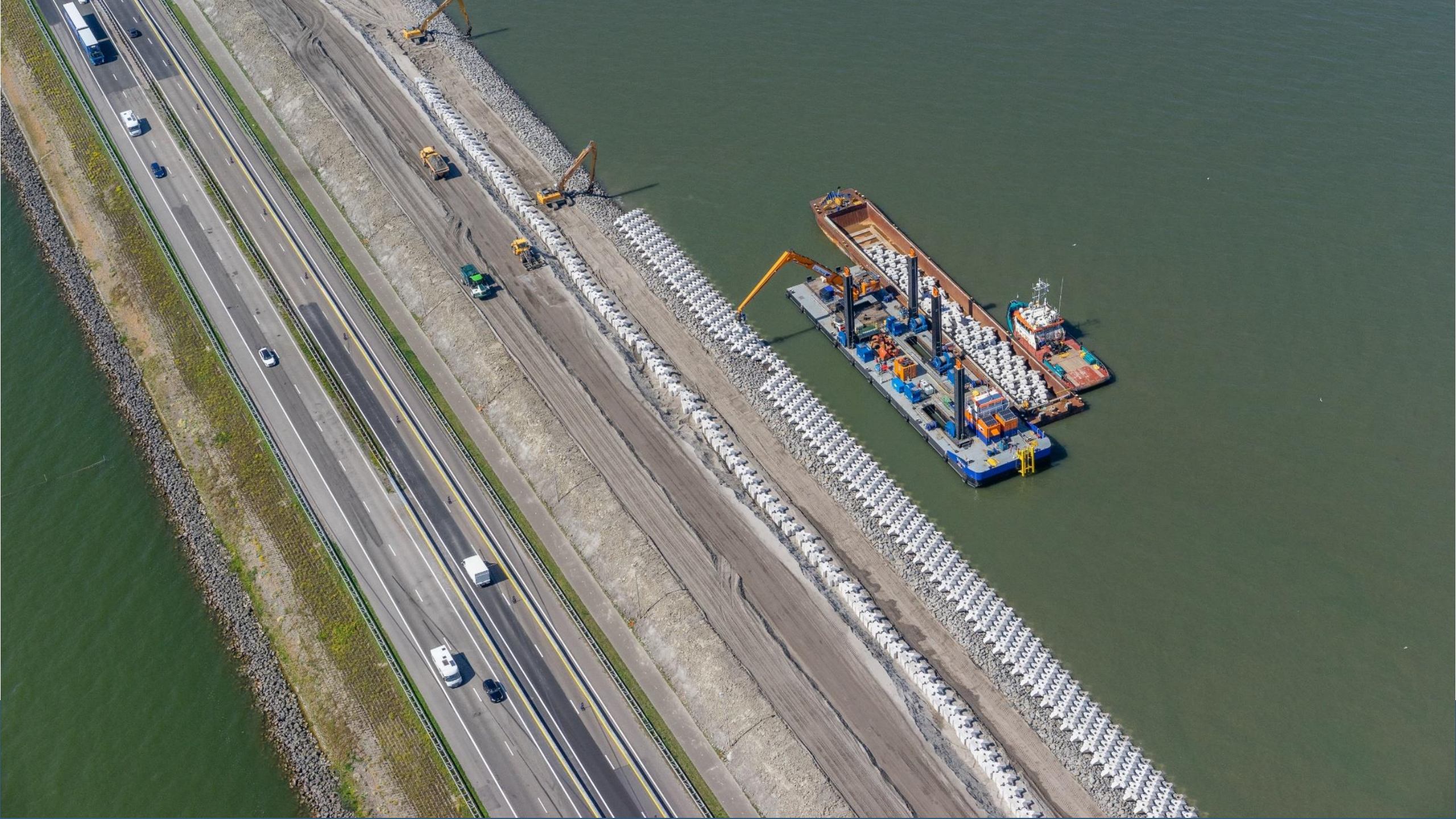
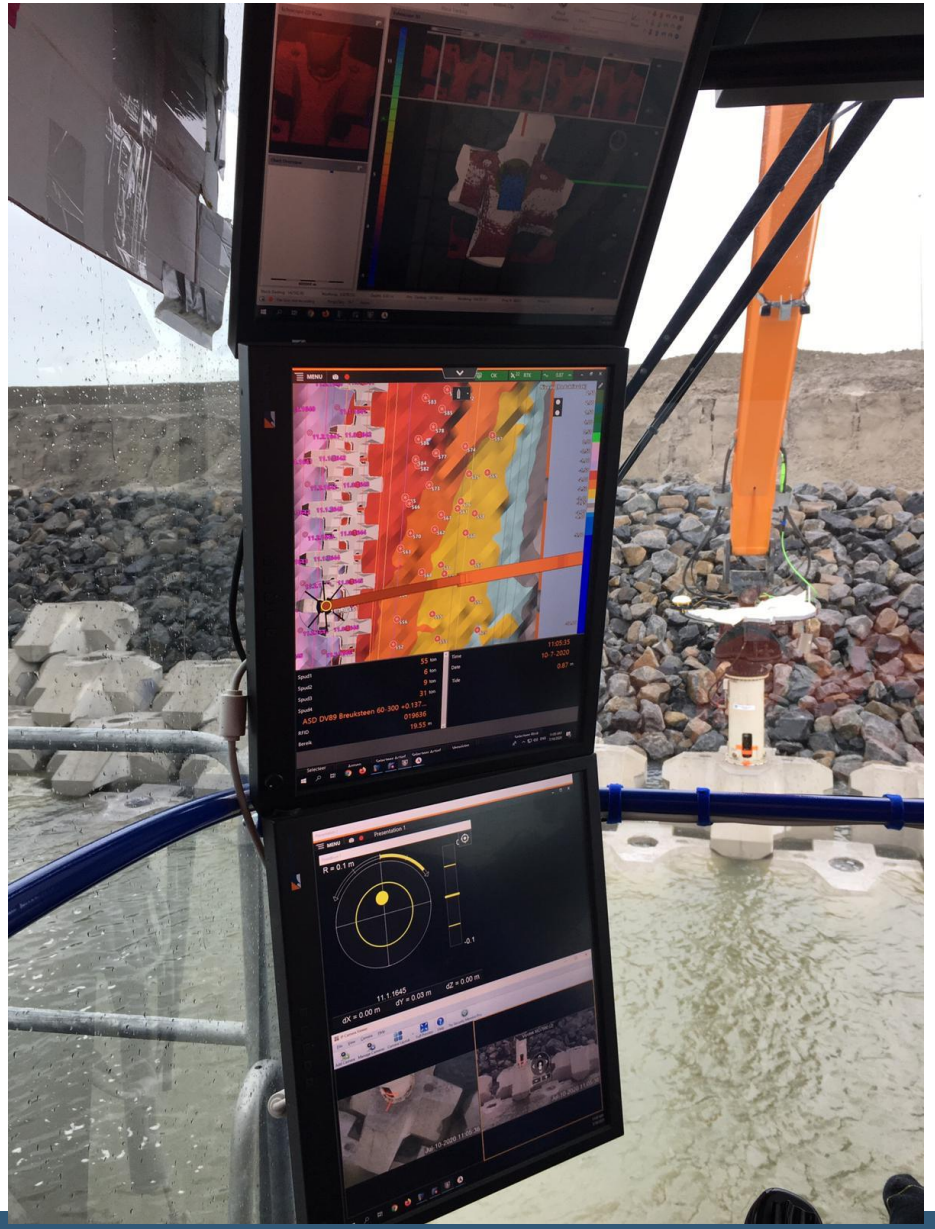
Block Placement

Under layer tolerances


VOLVO





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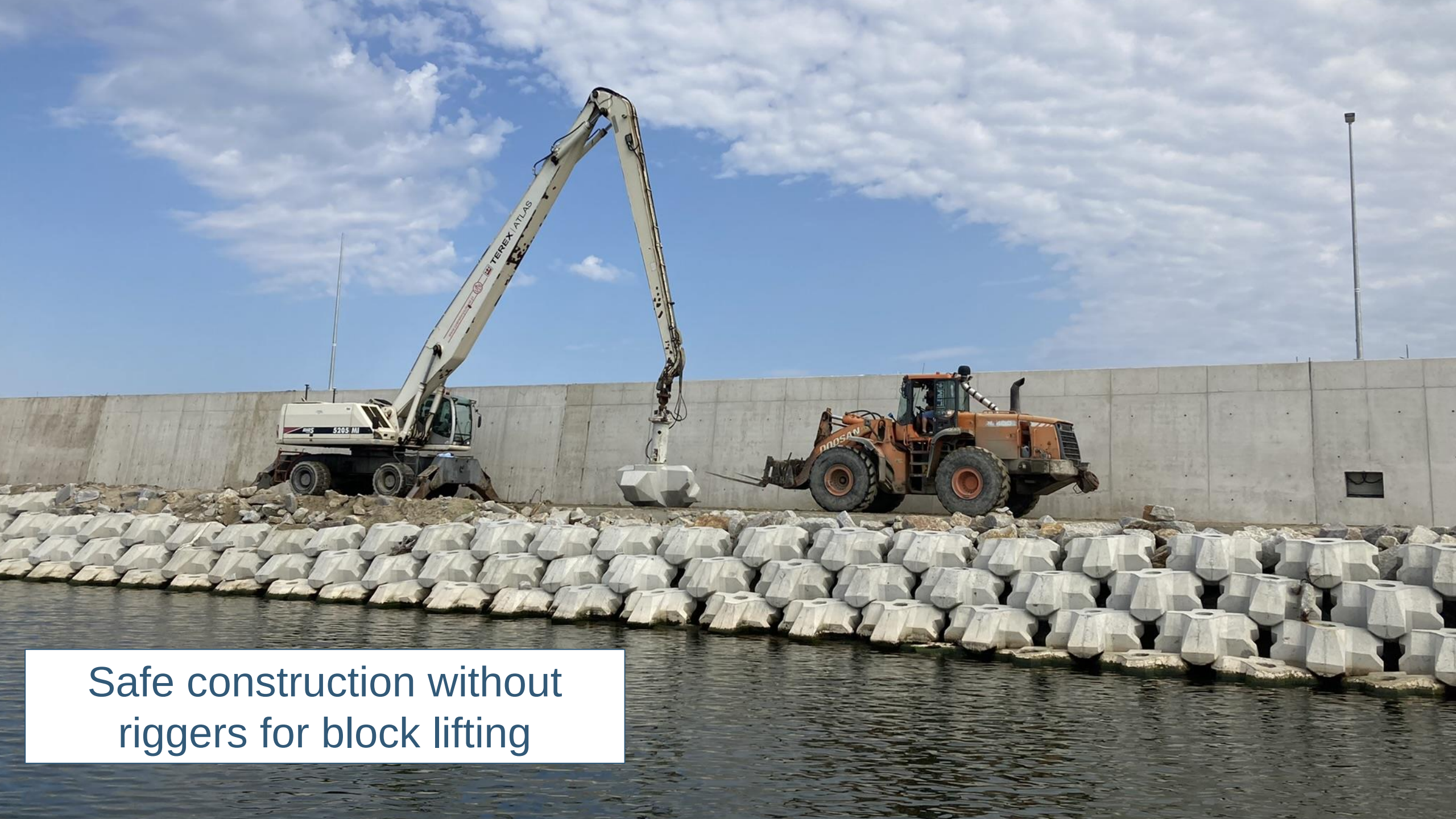

Safe construction without riggers for block lifting


PM
200
N
243
PM
190

Summary Project Experiences

Low block height simplifies filling of mould

Less sensitive for cracks and thermal stresses

Effective storage; careful stacking needed when going above 3 layer storage

Effective barge transport in multiple layers

Fast and safe placement with hydraulic gripper

Careful rock profiling facilitates block placement

Number of blocks required can be predicted prior to placement

Specials and Transitions

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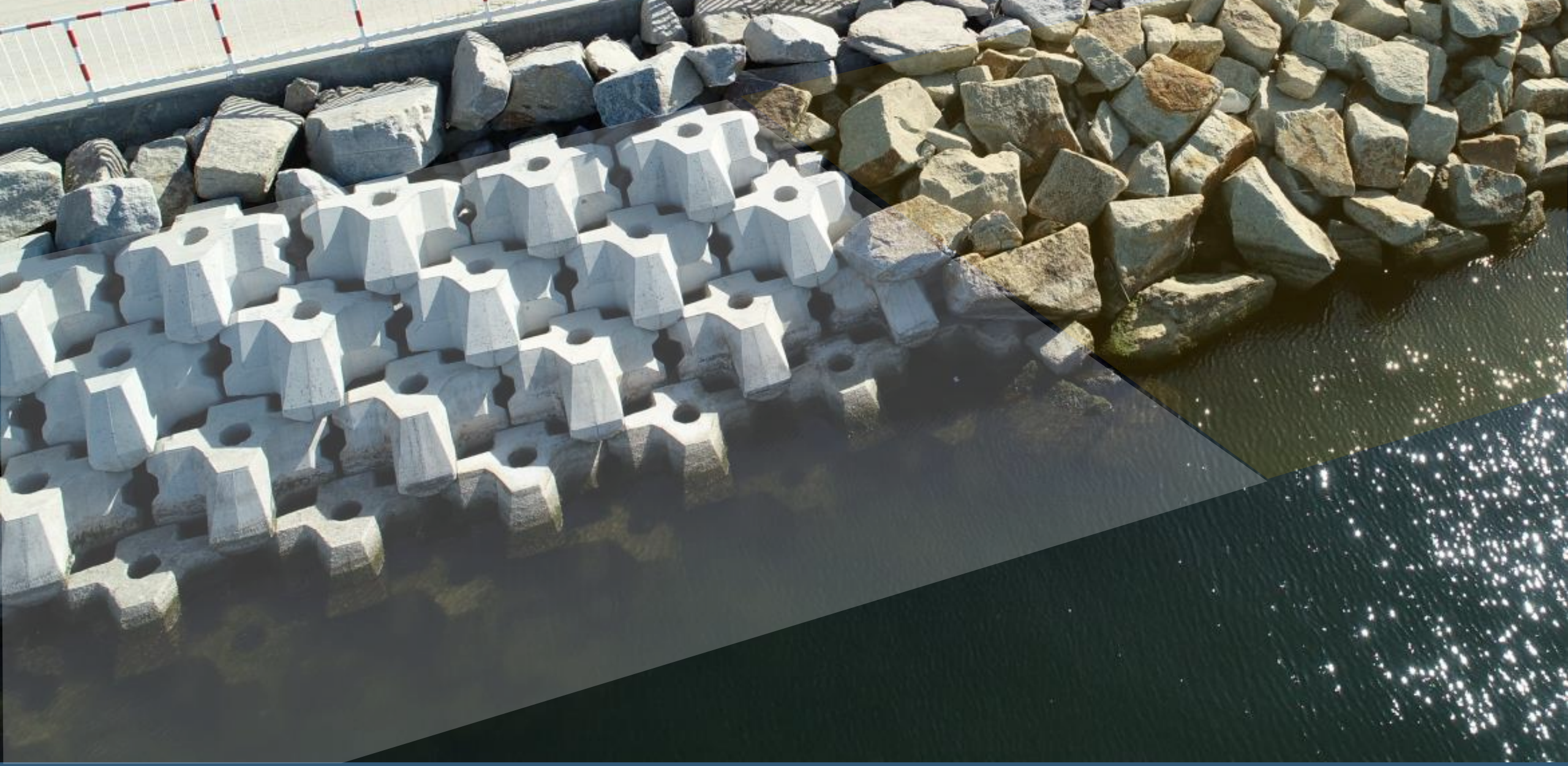

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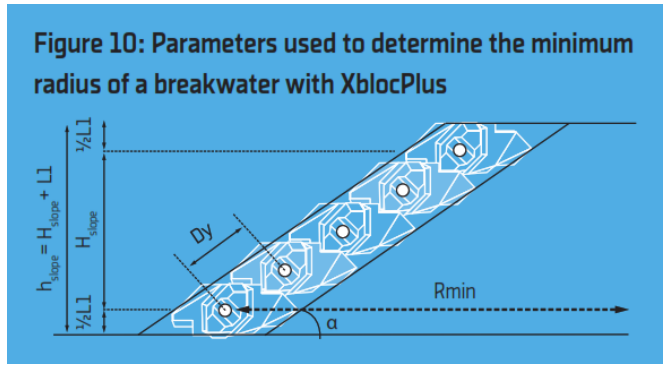
Curved Sections: XP-Wing and XP-Curve

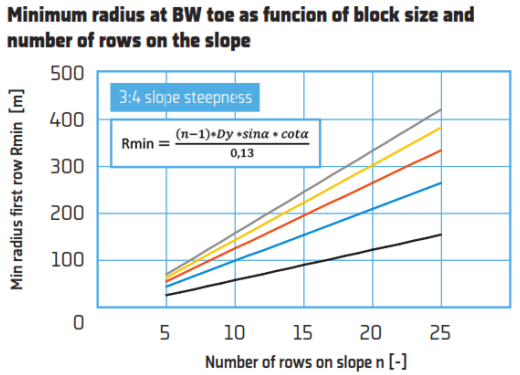
- Mild curves can be built with normal XblocPlus

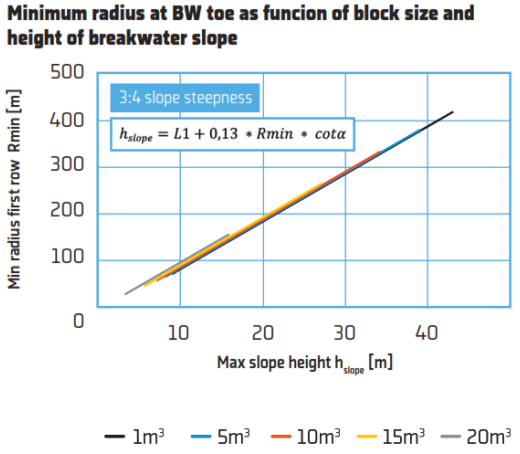
Minimum radius depends on

- Block size
- Slope steepness
- Breakwater height

- Example: 20m high breakwater: radius 200m







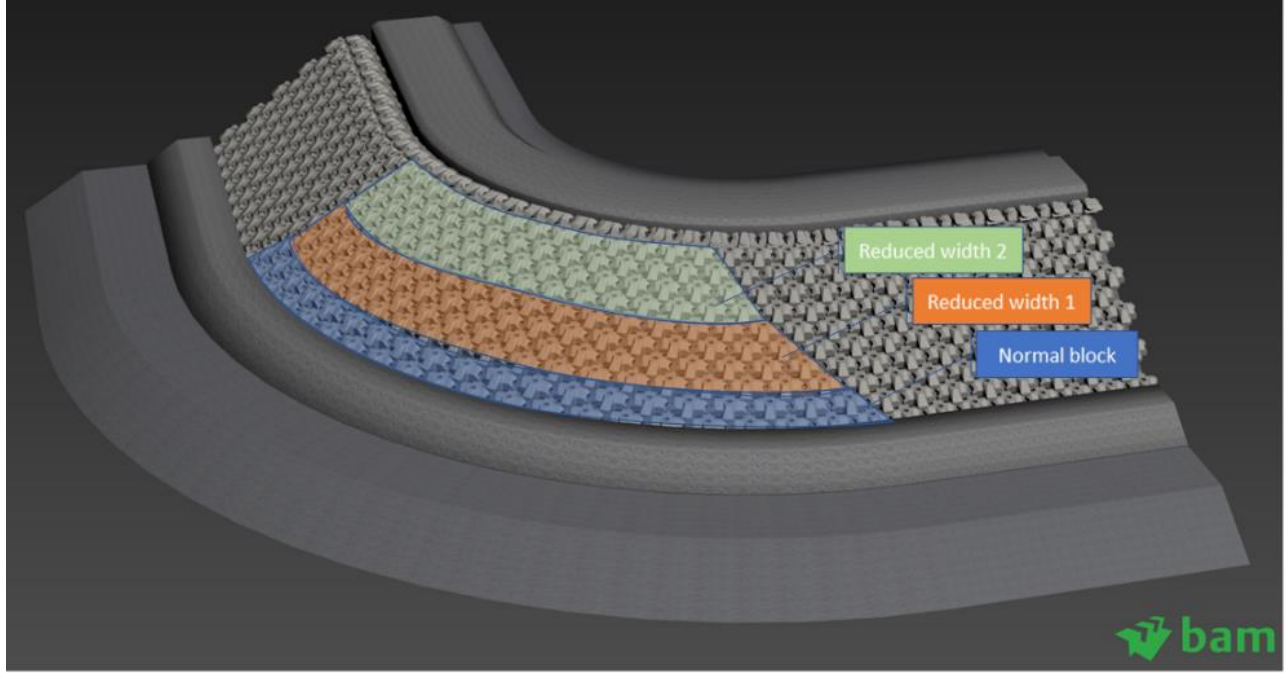
Medium Curves: XP-Wing

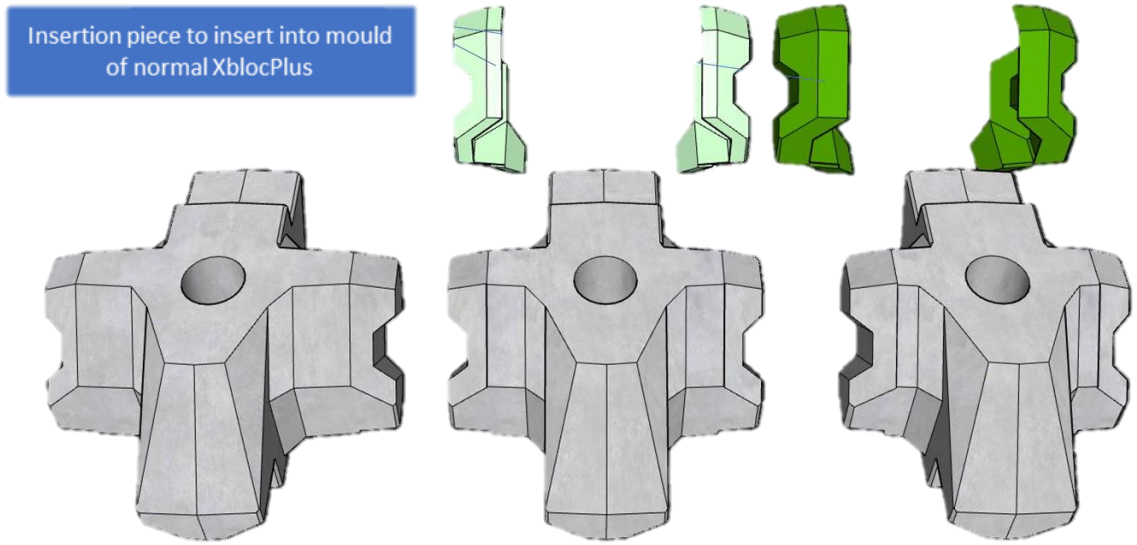
Minimum radius is reduced by 50% compared to normal XblocPlus.

The radius still depends on:

- Block size
- Slope steepness
- Breakwater height

Insertion pieces lead to reduced wingspan.

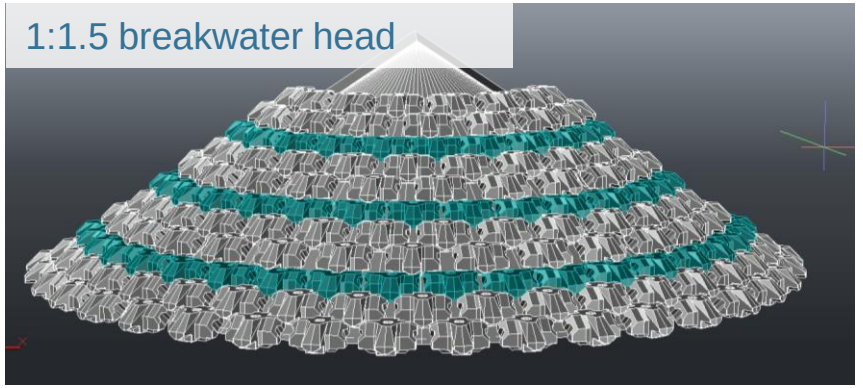


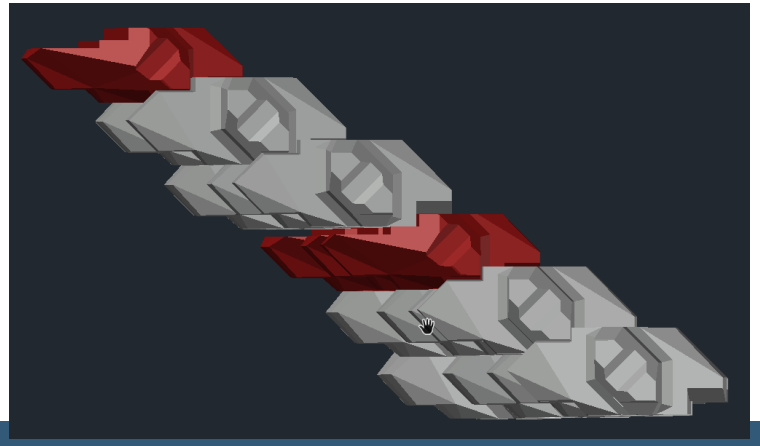


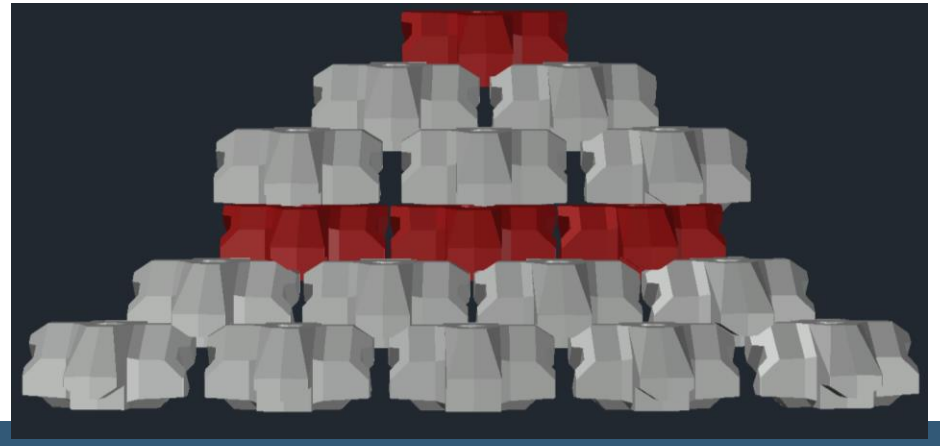
Sharp Curves and Breakwater Heads: XP-Curve

Where Dx becomes too small, XP-Curve is used; above this XblocPlus starts with normal Dx

The ratio between XP-Curve and XblocPlus on the section depends on the radius







Semi-3D tests in DMC flume:

- 4m3 XblocPlus
- Radius at toe 30m
- Slope steepness 1:1.5

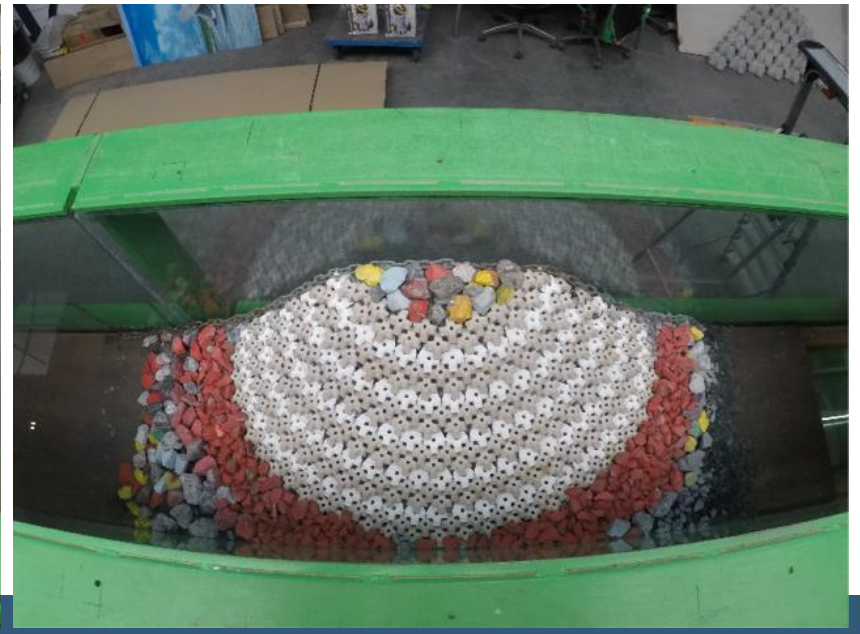
s.o.d at Hs/ΔDn=3.75 for wind waves

s.o.d at Hs/ΔDn=3.25 for swell waves

Tests continue in Q1 & Q2 2023:

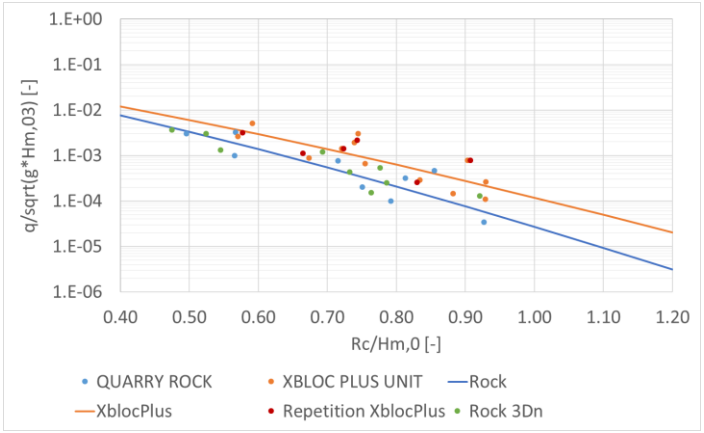
- Further semi-3D tests to improve stability on roundhead
- Full 3D tests

Objective for roundhead: same block size as on trunk without transition



Overtopping Reduction

- Roughness factor for different armour units based on CLASH model tests
- XblocPlus and rock armour tested for same setup and conditions
- Based on this research roughness coefficient XblocPlus $\gamma_f = 0.45$
- XblocPlus layer visually smooth, but hydraulically rough (similar to Xbloc)



Comparison with other blocks:

Xbloc $\gamma_f = 0.44$

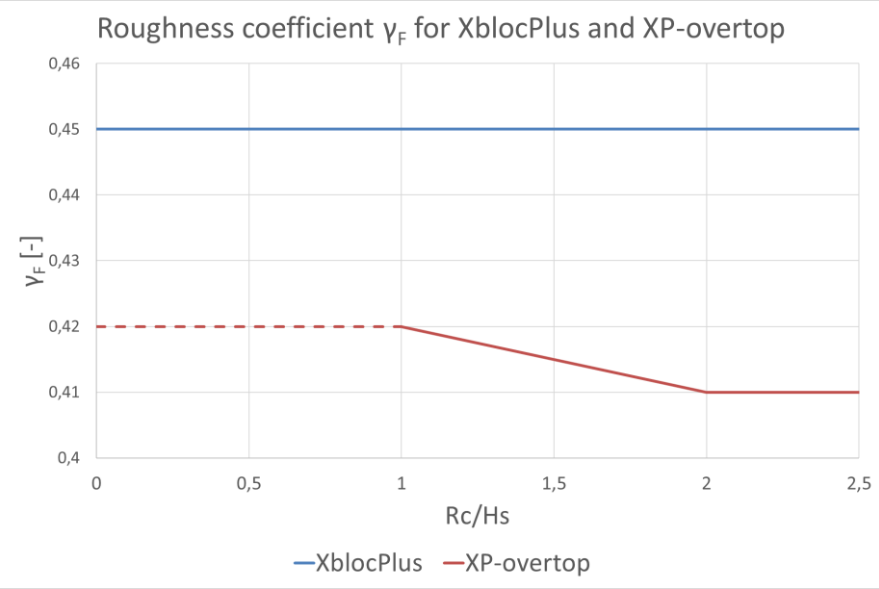
XblocPlus $\gamma_f = 0.45$

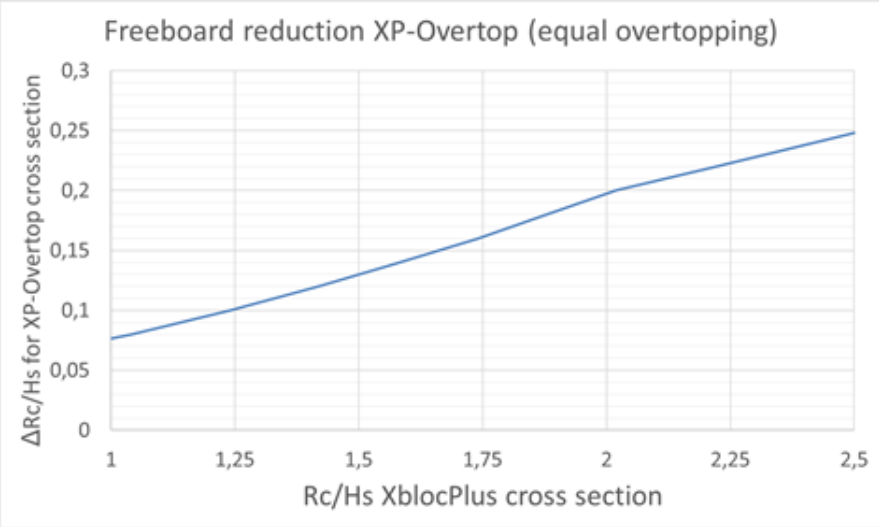
Accropode $\gamma_f = 0.46$

Single layer cube $\gamma_f = 0.49$

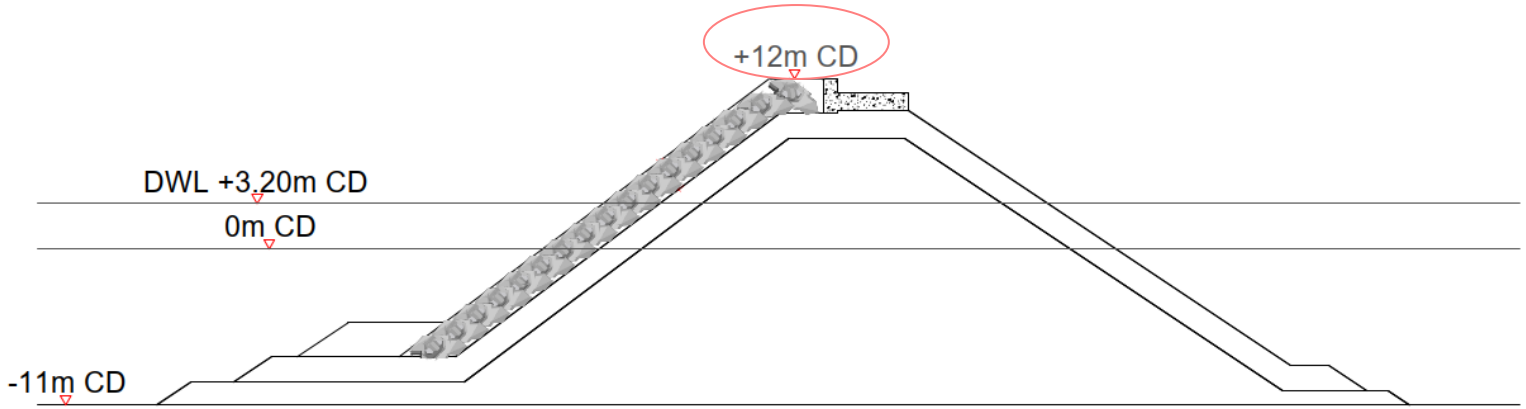
Reduction of Overtopping with XP-Overtop

- Unit with extra roughness
- To be placed high on the slope
- 23% extra concrete in the unit
- Allows reduction of crest height (0,5-1,5m)
- Can be applied as climate adaptation in case of sea level rise

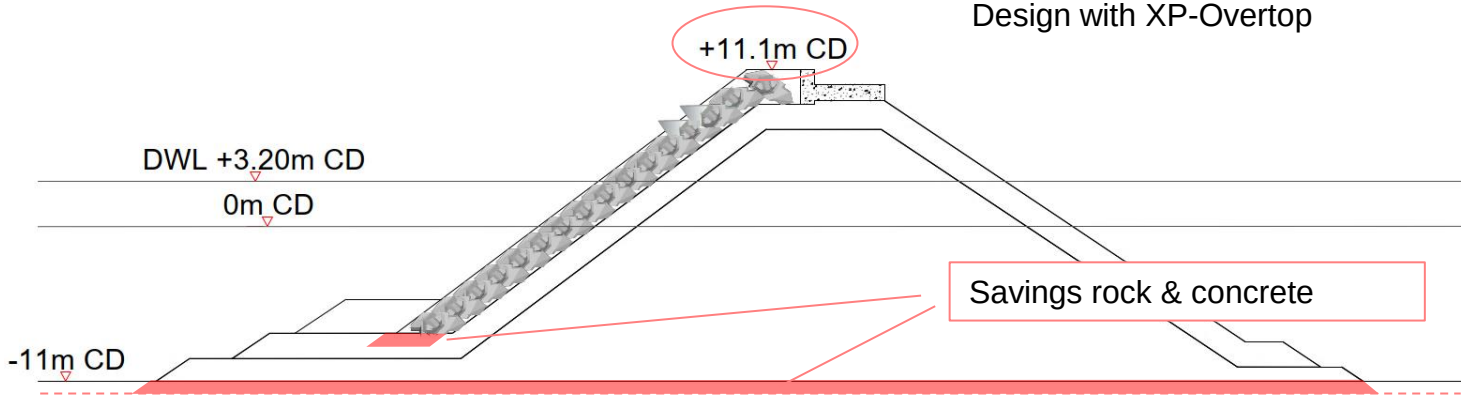




Design with normal XblocPlus



Design with XP-Overtop



Substantial reduction in crest level -> reduced rock quantities; construction time; CO2 emissions and costs

Architectural adaptation to blend in natural areas

Conclusions

XblocPlus offers wave protection which is:

- Reliable and Resilient
- Economical
- Ecological
- Sustainable
- Aesthetic

DMC keeps innovating to improve Xbloc technology with focus on constructability & nature inclusive designs

For more information: website / Linkedin / Guidelines *(click on icons)*