XSTONE DESIGN GUIDELINE



Q4 2026
Holcim Coastal

HOLCIM

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*Expected update Q1 2027

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1.0 / INTRODUCTION

1.1 MEET XSTONE

Xstone is a versatile bulk concrete armour unit, engineered to protect against waves and currents, while enhancing ecological benefits, supporting biodiversity, and reducing material use.
Xstone's main properties and benefits are listed below:

Block shape and structure

- High stability through weight and **interlocking** of X-shape
- Stable at **very steep slopes (1:1)**
- **Structure porosity of 60%**
- **Re-usable** block

Wide range of applications

Xstone can be applied in the following hydraulic and coastal structures:

- Breakwaters
- Foreshore dams
- Groynes
- River guiding dams
- Bed & bank protection
- Offshore scour protection
- Collision protection works

Large scale automated production

- Produced in high quantities in an automated dry-cast production facility

Optimized logistics

- Efficient storage and transportation since Xstones are easily stacked

Installation in bulk

- Xstone units are placed in bulk, using a crane with a sorting gripper, orange peel grab or a (double) stone clamp
- Wheel loader placement is also an option

Low CO_2 & material use

- Made using low CO_2* binders in combination with recycled materials
- Lower material per m^3 compared to natural stone due to high structure porosity and very steep slopes

Habitat creation

- Bio-active concrete mix designs promote settlement of sessile species, enhancing the associated biodiversity
- Structure porosity create varied habitats and shelter to mobile species

1.2 PURPOSE OF THE DOCUMENT

This document aims to assist designers in easily creating cross-sections with Xstone for concept designs. Installation, logistics, production, and material properties are also covered to support an integrated design approach.

The final design remains the responsibility of the designer, who must account for various factors influencing the design. Physical model tests are recommended to verify the stability of the design.

*The used binder has a minimum reduction of 30% lower GWP (kg CO2e/t, A1-A3 scope) compared to Portland Cement (CEM I/Type I) reference.

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2.0 / BLOCK SHAPE

Xstone's shape is engineered to optimize technical performance, enhance environmental benefits, simplify installation and improve production efficiency. The key attributes are:

Structural Stability: Its X-shape enables interlocking between units, enhancing stability.

Robustness: Its sturdy shape allows bulk installation from various heights.

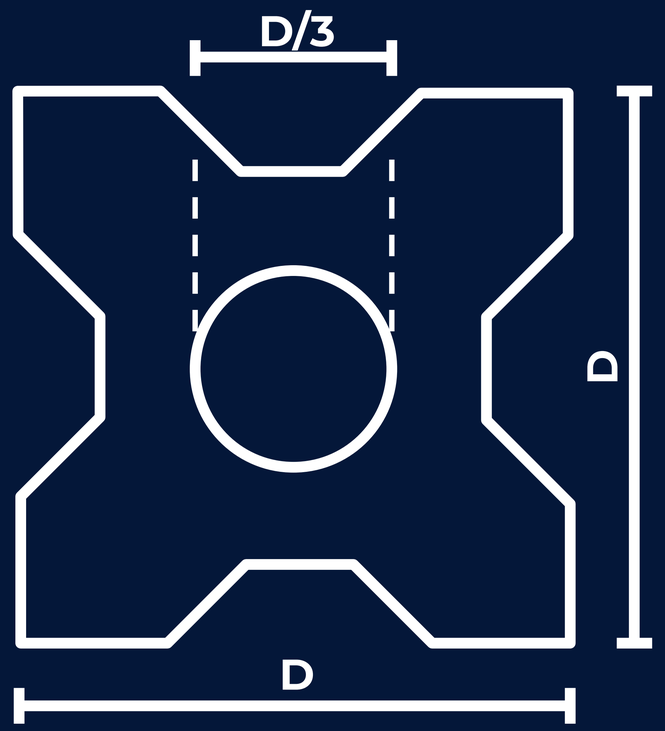
Habitat Creation: Bioactive concrete and high porosity support habitat formation.

Efficient Material Use: High porosity and stability at steep slopes reduce material consumption.

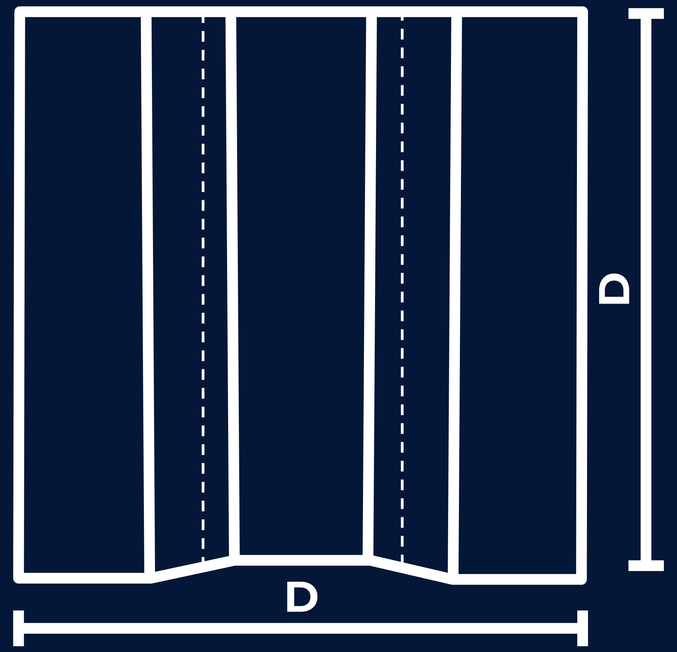
Transport & Storage: Flat surfaces enable easy stacking, simplifying logistics.

Production Efficiency: 2D shape facilitates dry-cast automated production.

The main dimensions of Xstone are:



Top view



Side view

xstone

Package →

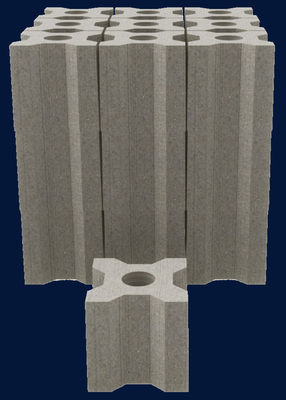
Block →



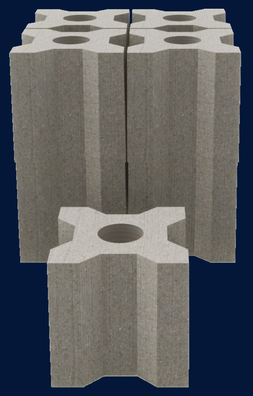
Xstone 20



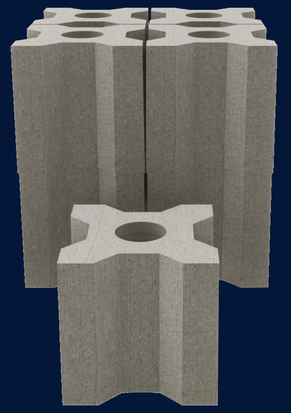
Xstone 30



Xstone 40



Xstone 50



Xstone 60

Type	D [cm]	Block mass [kg]	Blocks per m^3 structure [-]	Package: Dimensions (l x b x h)	Package: Number of blocks per package	Package: Mass at s.g. 2.3 [kg]
Xstone 20*	20	12.3	75.0	1.2m x 1.2m x 1.0m	180	2.214
Xstone 30	30	41.4	22.2	1.2m x 1.2m x 0.9m	48	1.987
Xstone 40	40	98.2	9.4	1.2m x 1.2m x 1.2m	27	2.652
Xstone 50*	50	191.8	4.8	1.0m x 1.0m x 1.0m	8	1.535
Xstone 60*	60	331.5	2.8	1.2m x 1.2m x 1.2m	8	2.652

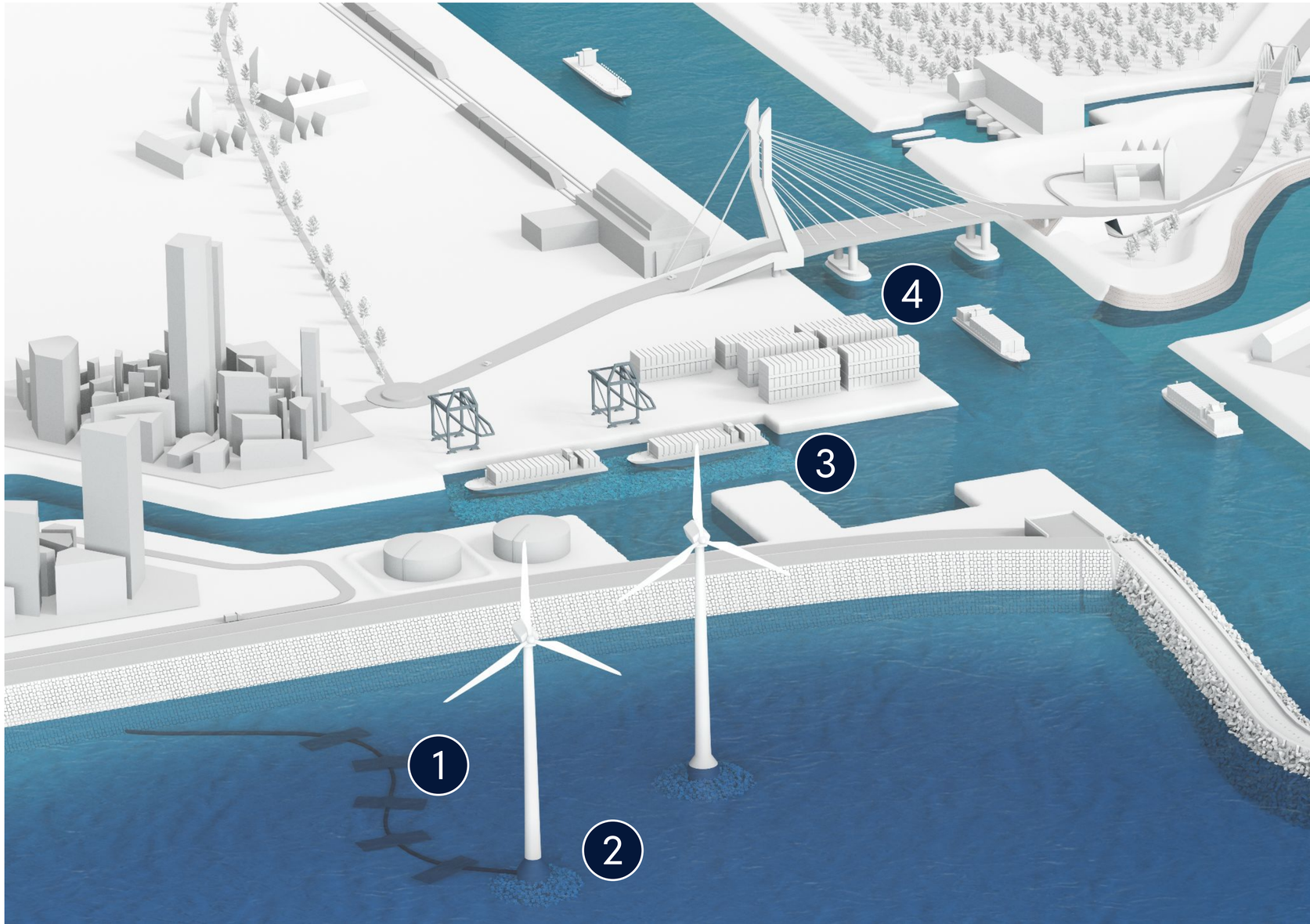
**Available upon request*

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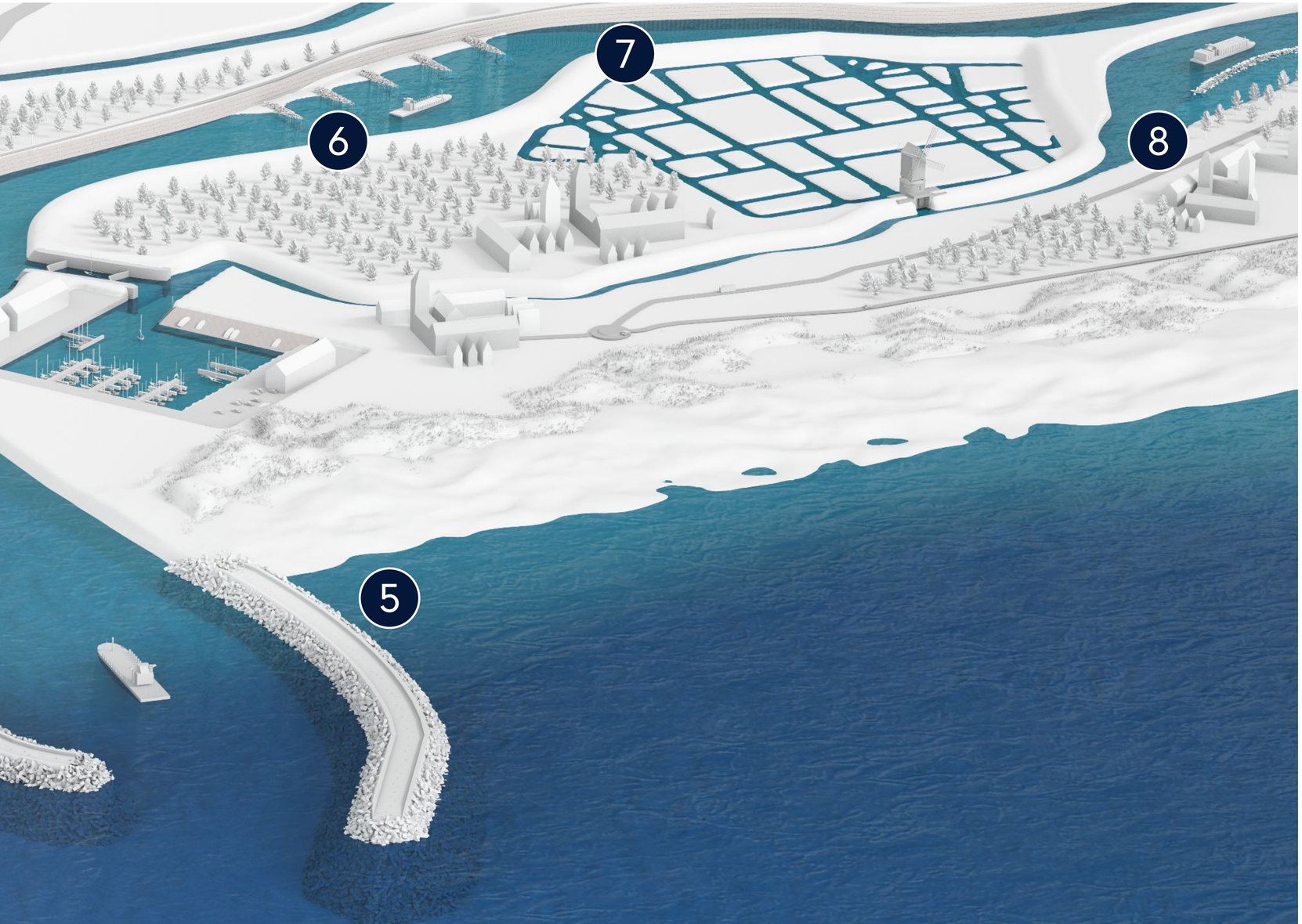
3.0 / APPLICATIONS

Xstone can be used as alternative to rock in hydraulic, coastal and port engineering. With its high stability, it offers protection against both currents and waves, making it suitable for a wide range of applications, including:

1. Cable crossings
2. Offshore wind scour protection
3. Scour protection for berthing structures
4. Collision protection works



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5 Breakwaters & foreshore dams

6 Groynes

7 Bed and bank protection

8 Longitudinal / river guiding dams

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4.0 / PROTECTION AGAINST WAVES

Xstone applied as reef breakwaters
Reef breakwaters are low-crested, rubble-mound structures constructed from a single type of material. They are designed to dissipate wave energy, reduce shoreline erosion and protect coastal infrastructure. Xstone's use in reef breakwaters provides a versatile solution that fulfills both engineering demands and environmental objectives. By mimicking natural reefs, an Xstone reef breakwater provides multiple benefits such as:

1. **Wave Protection:** As waves interact with rough, porous Xstone breakwaters, wave energy is dissipated. Xstone's shape enables interlocking between units, enhancing structural stability in addition to the stability provided by the block's weight.
2. **Efficient Use of Materials:** Xstone is stable at very steep slopes (up to 1:1), reducing material use compared to traditional rock breakwaters.
3. **Environmental Benefits:** Its high structural porosity (60%) promotes habitat creation, while the bio-active concrete mix design attracts species

Required unit size
The required unit size of Xstone for typical cross-sections of reef breakwaters depends on the design wave height, relative freeboard, and the structure's slope and can be calculated with the following formula:

$$D = 1.15 \cdot H_{m0}/\Delta N_s$$

where

D	Unit height (=1.15 D_n)	[m]
D_n	Nominal diameter (=0.87 D)	[m]
H_{m0}	Spectral significant wave height at toe	[m]
N_s	Stability number as specified in Table 4	[-]
Δ	Relative concrete density (ρ_c-ρ_w/ρ_c)	[-]
ρ_c	Mass density of concrete[1]	[kg/m^3]
ρ_w	Mass density of water	[kg/m^3]
R_c	Crest freeboard of structure	[m]

Design stability numbers (N_s) for Xstone, presented in Table 4, are based on wave flume tests with a wave steepness of s_{op} = 4%. The design stability numbers account for an average crest height reduction of 1 $\cdot D_n$ and include a 10% safety factor.

[1] Xstone has a standard density of 2.300 kg/m^3, but can be produced with a density of up to 2.700 kg/m^3.

Xstone is available in the standard sizes shown in Table 4-1. Additional sizes may be available upon request.

Table 4: Stability numbers (N_s) based on slope and relative freeboard (R_c/D_n)

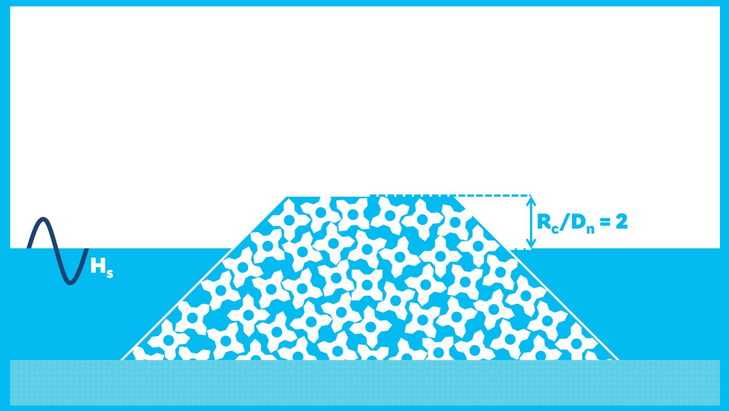
Slope (V:H)	N_s		
	R_c/D_n = 2	R_c/D_n = 0	R_c/D_n = -2
1:1	2.9	3.6	3.7
1:1.5	3.5	3.5	4.2

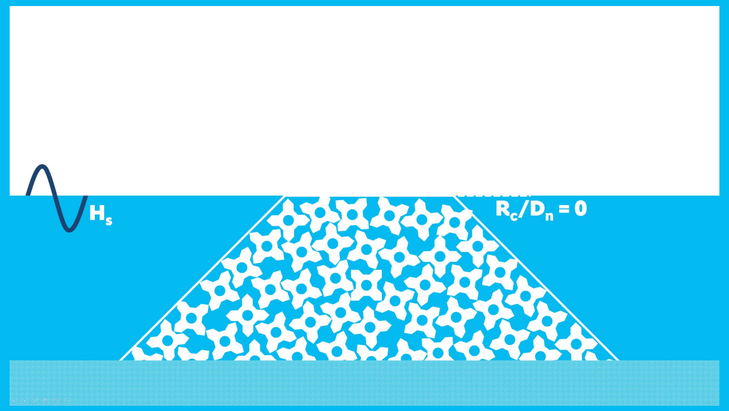
Design table
The required Xstone sizes, their design wave height and properties are shown in Table 4-1 and Table 4-2. The table is based on a slope of 1:1 with densities of ρ_c = 2.300 kg/m^3 and ρ_w = 1.030 kg/m^3. Table 4-2 is based on a slope of 1:1.5 with densities ρ_c = 2.300 kg/m^3 and ρ_w = 1.030 kg/m^3.

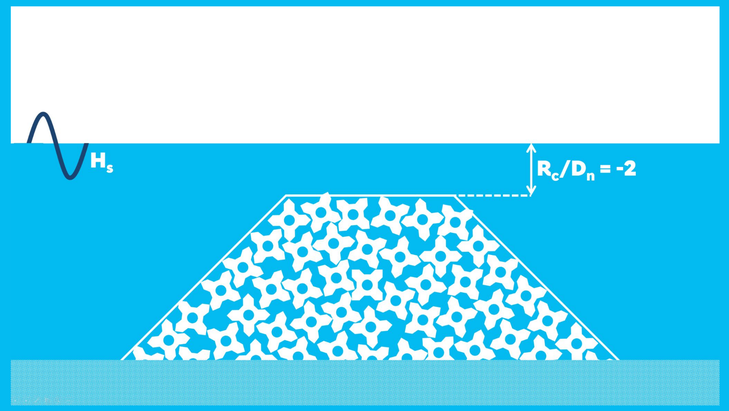
4.1 / DESIGN TABLE WAVES

cot(α) = 1

Type	Unit height D [cm]	Unit mass M [kg]	Design wave height $R_c/D_n = 2$ H_{m0} [m]	Design wave height $R_c/D_n = 0$ H_{m0} [m]	Design wave height $R_c/D_n = -2$ H_{m0} [m]	Unit concrete volume V [litres]	Units per m^3 [-]
Xstone 20	20	12.3	0.6	0.8	0.8	5.3	75.0
Xstone 30	30	41.4	1.0	1.2	1.3	18.0	22.2
Xstone 40	40	98.2	1.3	1.6	1.7	42.7	9.4
Xstone 50	50	191.8	1.7	2.1	2.2	83.4	4.8
Xstone 60	60	331.5	2.0	2.5	2.6	144.1	2.8







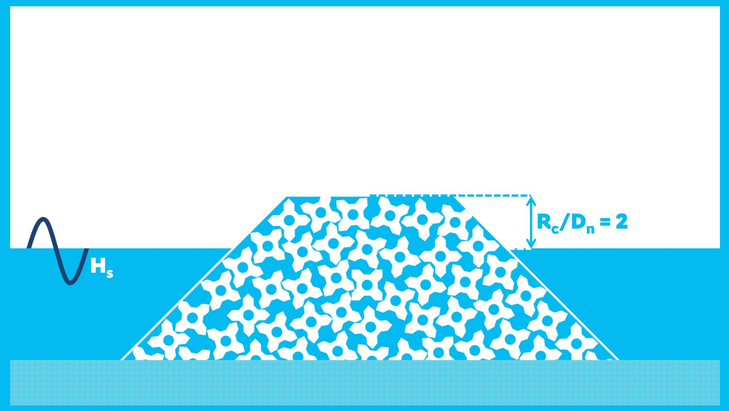


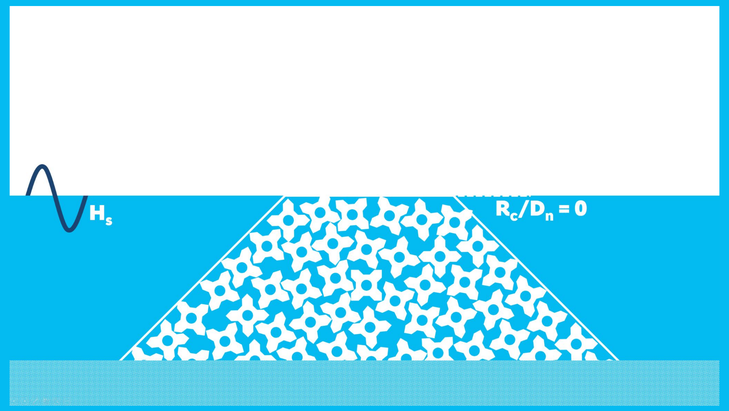
4.2 / DESIGN TABLE WAVES

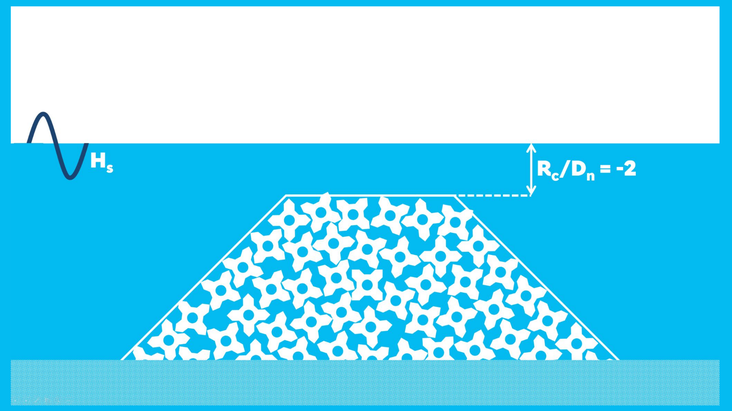
cot(α) = 1.5

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Type	Unit height D [cm]	Unit mass M [kg]	Design wave height $R_c/D_n = 2$ H_{m0} [m]	Design wave height $R_c/D_n = 0$ H_{m0} [m]	Design wave height $R_c/D_n = -2$ H_{m0} [m]	Unit concrete volume V [litres]	Units per m^3 [-]
Xstone 20	20	12.3	0.7	0.9	0.9	5.3	75.0
Xstone 30	30	41.4	1.1	1.3	1.4	18.0	22.2
Xstone 40	40	98.2	1.5	1.7	1.8	42.7	9.4
Xstone 50	50	191.8	1.9	2.1	2.3	83.4	4.8
Xstone 60	60	331.5	2.2	2.6	2.7	144.1	2.8





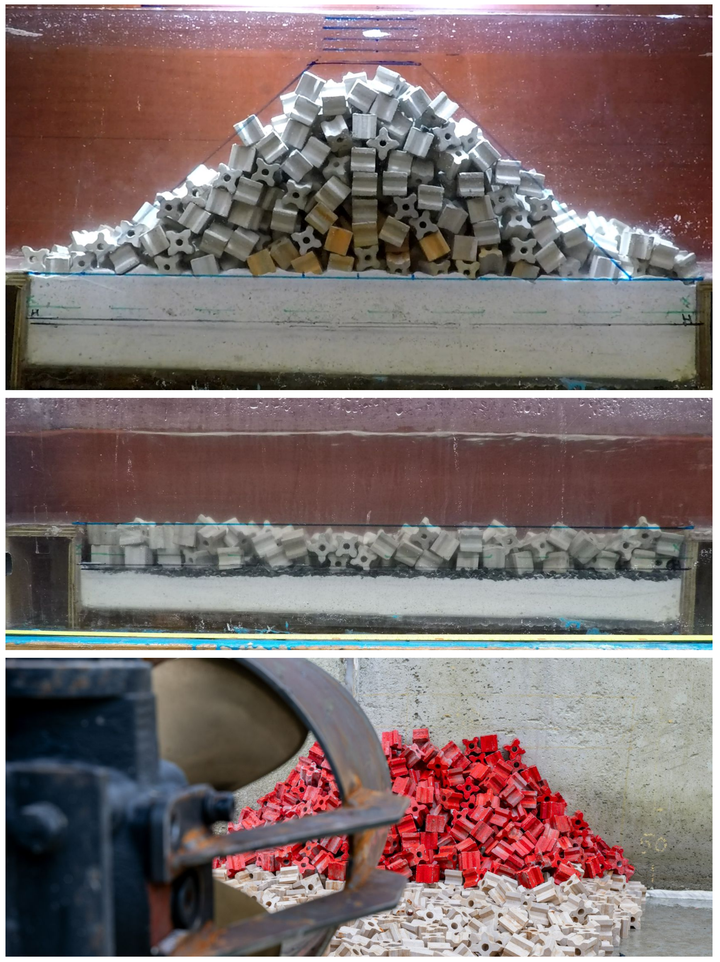


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5.0 / PROTECTION AGAINST CURRENTS

Xstone's application in hydraulic infrastructure
Xstone has various applications in hydraulic engineering, including river guiding dams, groynes, scour and bed protection as well as collision protection works. Its use in hydraulic engineering has multiple benefits:

1. **Flexible and adaptable:** Groynes or guide dams can be built entirely from Xstone, creating flexible structures that can be adapted to mitigate the effects of climate change.
2. **Efficient use of materials:** Its design allows for a steeper slope (up to 1:1), significantly reducing material usage compared to traditional river structures.
3. **Environmental benefits:** Its high structural porosity (60%) promotes habitat creation, while the bio-active concrete mix design attracts species
4. **Placement and transport:** Xstones are placed in bulk using a crane with a sorting gripper, orange peel grab or a (double) stone clamp and can be transported in bulk via river barges.



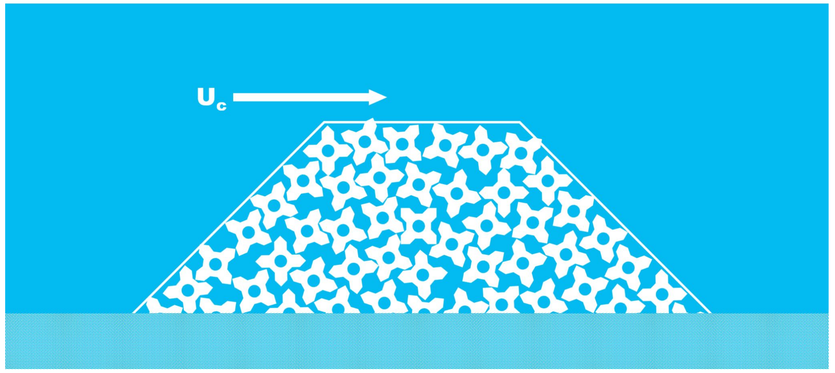
Required unit size
The required unit size of Xstone depends mainly on the design near-bed critical velocity (Table 5-1). Design near-bed critical velocities (U_c) were derived for Xstone through physical model tests. The model tests included two model setups with Xstone: as bed protection and within a river groyne. These near-bed critical velocities were measured at the Xstone units and therefore are not depth averaged velocities. The velocities are measured before failure of the structure occurred and include a 10% safety factor.

Propeller wash loading
Xstone is also tested for propeller wash loading. The required dimensions of Xstone depend on the critical bed velocity (Table 5-2). Design critical velocities ($U_{b,max}$) were derived for Xstone through physical model tests. In these tests, Xstone was evaluated as flat bed protection under the influence of propeller wash. The velocities are measured before failure of the structure occurred and include a 10% safety factor.

Design table
The required Xstone sizes, their design near-bed critical velocity and properties are shown in Table 5-1 and 5-2. The table is based on a concrete density of ρ_c = 2.300 kg/m^3

5.1 / DESIGN TABLE CURRENT

Type	Unit height D [cm]	Unit mass M [kg]	Design critical velocity U_c [m/s]	Unit concrete volume V [litres]	Units per m^3 [-]
Xstone 20	20	12.3	2.2	5.3	75.0
Xstone 30	30	41.4	2.7	18.0	22.2
Xstone 40	40	98.2	3.1	42.7	9.4
Xstone 50	50	191.8	3.5	83.4	4.8
Xstone 60	60	331.5	3.8	144.1	2.8



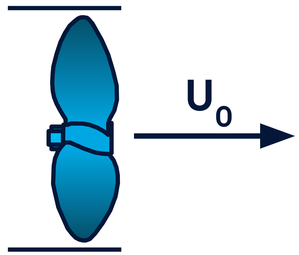
Note: The values shown represent the most conservative figures derived from a wide range of test conditions, including a 10% safety factor. These values serve as a baseline; however, model testing is recommended for other conditions.

xstone



5.2 / DESIGN TABLE PROPELLER WASH

Type	Size D [cm]	Mass M [kg]	Design critical bed velocity $U_{b,max}$ [m/s]	Layer thickness (2 $D_{n,50}$) [m]	Blocks per m^3 [-]
Xstone 20	20	12.3	2.3	0.35	75.0
Xstone 30	30	41.4	2.8	0.52	22.2
Xstone 40	40	98.2	3.3	0.70	9.4
Xstone 50	50	191.8	3.7	0.87	4.8
Xstone 60	60	331.5	4.0	1.04	2.8



Note: The values shown represent the most conservative figures derived from a wide range of test conditions, including a 10% safety factor. These values serve as a baseline; however, model testing is recommended for other conditions.



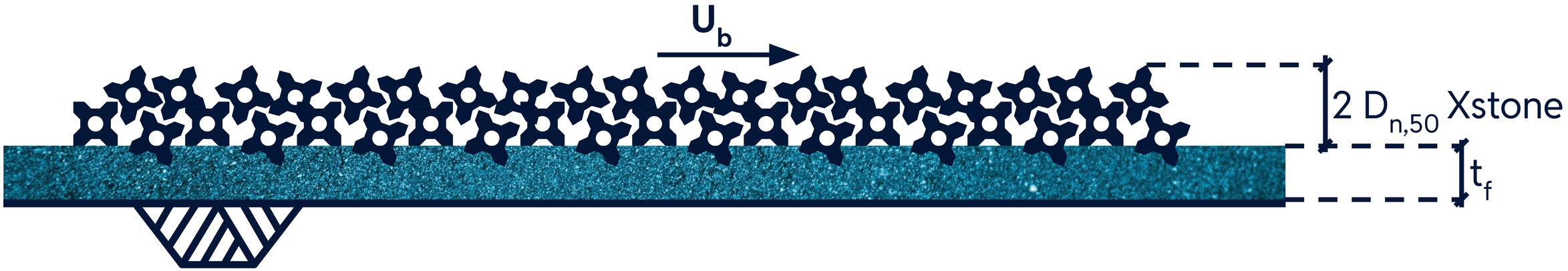
6.0 / GRANULAR FILTER LAYER

Geometrically open & closed filters

Geometrically open & closed filters
Depending on the hydraulic boundary conditions, layer thickness and geotechnical properties, a filter layer may be required in combination with Xstone.

When Xstone is applied in a double-layer configuration, Table 6.1 proposes a geometrically open and closed filter. The geometrically closed filter is based on the guidelines of CIRIA/CUR/CETMEF (2007), which are derived from the application with rock. The geometrically open filter is derived from physical model tests in a flow flume.

Note: These configurations are meant as starting point for concept design. Depending on project-specific circumstances, additional research or further testing may be necessary to confirm suitability and feasibility.



CIRIA, CUR, CETMEF (2007). The Rock Manual: The use of rock in hydraulic engineering (2nd edition). CIRIA C683. London: CIRIA.

6.1 / GRANULAR FILTERLAYER

Type	Size D [cm]	Mass M [kg]	Closed filter: proposed rock grading [mm]	Minimum filter thickness t_f [m]
Xstone 20	20	12.3	30/90	0.2
Xstone 30	30	41.4	30/90	0.2
Xstone 40	40	98.2	45/125	0.2
Xstone 50	50	191.8	45/125	0.2
Xstone 60	60	331.5	90/180	0.3

Type	Size D [cm]	Mass M [kg]	Open filter: proposed rock grading [mm]	Minimum filter thickness t_f [m]
Xstone 20	20	12.3	20/60	0.2
Xstone 30	30	41.4	30/90	0.2
Xstone 40	40	98.2	30/90	0.2
Xstone 50	50	191.8	45/125	0.2
Xstone 60	60	331.5	45/125	0.2

8.0 / PRODUCTION

The shape of Xstone is optimized for it to be produced with many existing dry cast concrete technologies, allowing for local production and flexibility. Below, the three different methodologies for production are elaborated:

1. Production at Holcim Coastal



At Holcim Coastal, we have a wide track record of projects. We are able to produce at a high production rate and are able to deliver Xstone with the following advantages:

- Use of low CO_2 binders during production
- Up to 100% recycled materials (with the exception of the binder)
- 5 different Xstone variants
    - Xstone regular (s.g. 2.3)
    - Xstone heavy (s.g. 2.7)
    - Xstone porous fine
    - Xstone porous coarse
    - Xstone shell

Holcim Coastal is situated at Hoorn 350, 2404HL, Alphen aan den Rijn, the Netherlands.

2. Local paver machine



Xstone can be produced on a local paver machine using a simplified steel mould adapted to the machine's vibration and compaction system.

Because paver machines already handle similar block geometries, only the mould needs to be customised, allowing small and medium precast factories to produce Xstone without new equipment.

A licensing model supports this local production approach. This keeps production local and economical while ensuring that every unit meets the required strength, shape and durability standards.

3. Egg Layer



Xstone can be produced efficiently on a standard concrete egg-layer. The egg-layer feeds earth-moist concrete into the mould, vibrates and compresses it, and then lifts the mould while moving forward, leaving freshly formed Xstone units on the production floor. Because the process uses conventional compaction and curing, factories can produce Xstone without major investments or new equipment. This makes Xstone compatible with almost any precast block producer worldwide.

To scale safely and consistently, Xstone is offered through a licensing model. This ensures that every Xstone block—regardless of where it is made—meets the hydraulic performance and durability requirements of the original design.

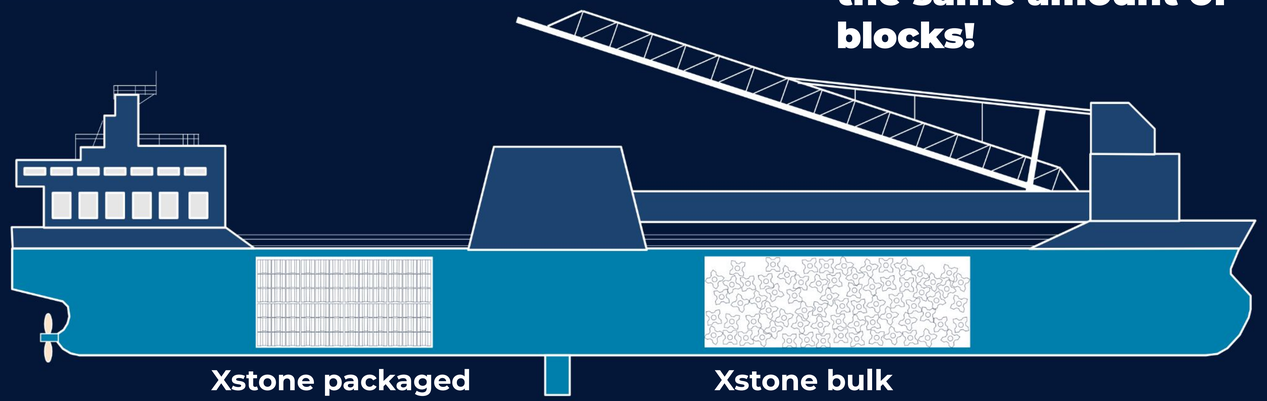
9.0 / LOGISTICS

Xstone is very efficient in transportation. The blocks are packaged in a compact manner. This results in transportation and installation savings, as the volume of the structure is much higher than the transported volume, see the example to the right.

Configuration of each block type is presented in the table below. Xstones are delivered without pallet by default, on request pallets are possible. When mechanically clamped, ensure the clamp is larger than the packaged dimension.

Type	D [cm]	Package: Dimensions (l x b x h)	Total Xstones in 1 package	Mass of package at s.g. 2.3 [kg]
Xstone 20	20	1.2m x 1.2m x 1.0m	180	2214
Xstone 30	30	1.2m x 1.2m x 0.9m	48	1987
Xstone 40	40	1.2m x 1.2m x 1.2m	27	2652
Xstone 50	50	1.0m x 1.0m x 1.0m	8	1535
Xstone 60	60	1.2m x 1.2m x 1.2m	8	2652

Xstone bulk takes up 50% more volume for the same amount of blocks!



Xstone packaged
- Compact
- 33% porosity
  (33% is air, 67% is concrete)
- With or without pallet

Xstone bulk
- Randomized
- 60% porosity
  (60% is air, 40% is concrete)

The efficient recommendation for transport

10.0 / INSTALLATION

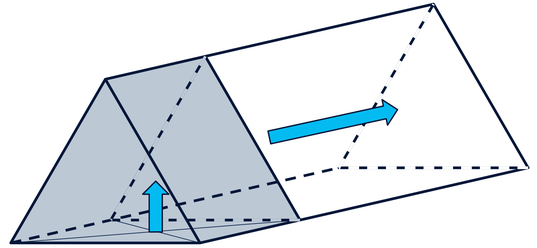
Storage on site
Xstones should be placed on flat a surface area consisting of concrete or compacted aggregate. Packages can be placed on top of each other, up to a maximum height of 2 packages.

Handling equipment
Xstone is compatible with most handling equipment. Examples are:

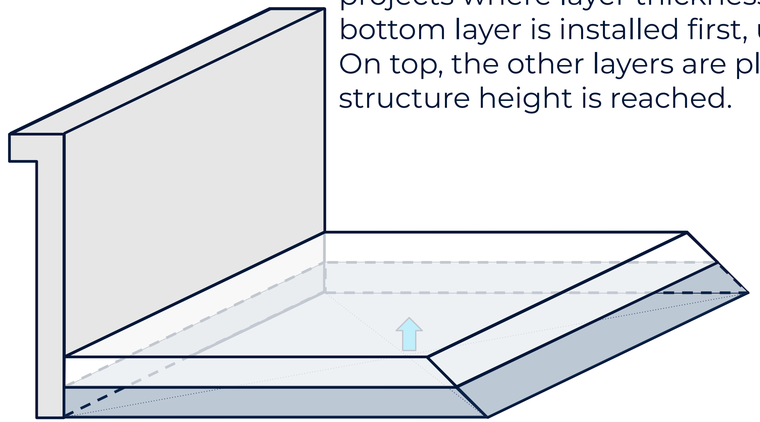
Equipment	Installation speed	Damage during handling	Suitable for packaged product	Suitable for bulk (random) product
Sorting gripper 	++	Minimal	Yes	No
Orange peel grab 	+	Moderate	Yes	Yes
Stone clamp 	+++	Minimal	Yes	No
Wheel loader 	+	Moderate	No	Yes

Placement method
Xstones are recommended to be placed with a minimum layer thickness of $2 \cdot D_n$. If the minimum layer thickness is used, install Xstones per 1 or 2 layers. The larger the release height, the larger the spread of the Xstones (especially when released under water). There are 2 methods for placement (up and out and grid structure) of larger structures that are recommended. These are elaborated to the right.

Method 1: Up and away
In this method, the first heap of Xstone is placed at the bottom and is built up from this central location until the required crest height is reached. Then, the structure is built outward, dropping the blocks just right of the constructed crest.



Method 2: Layer by layer
The layer by layer method is more suitable for projects where layer thickness is minimal. The bottom layer is installed first, using a grid method. On top, the other layers are placed until the desired structure height is reached.

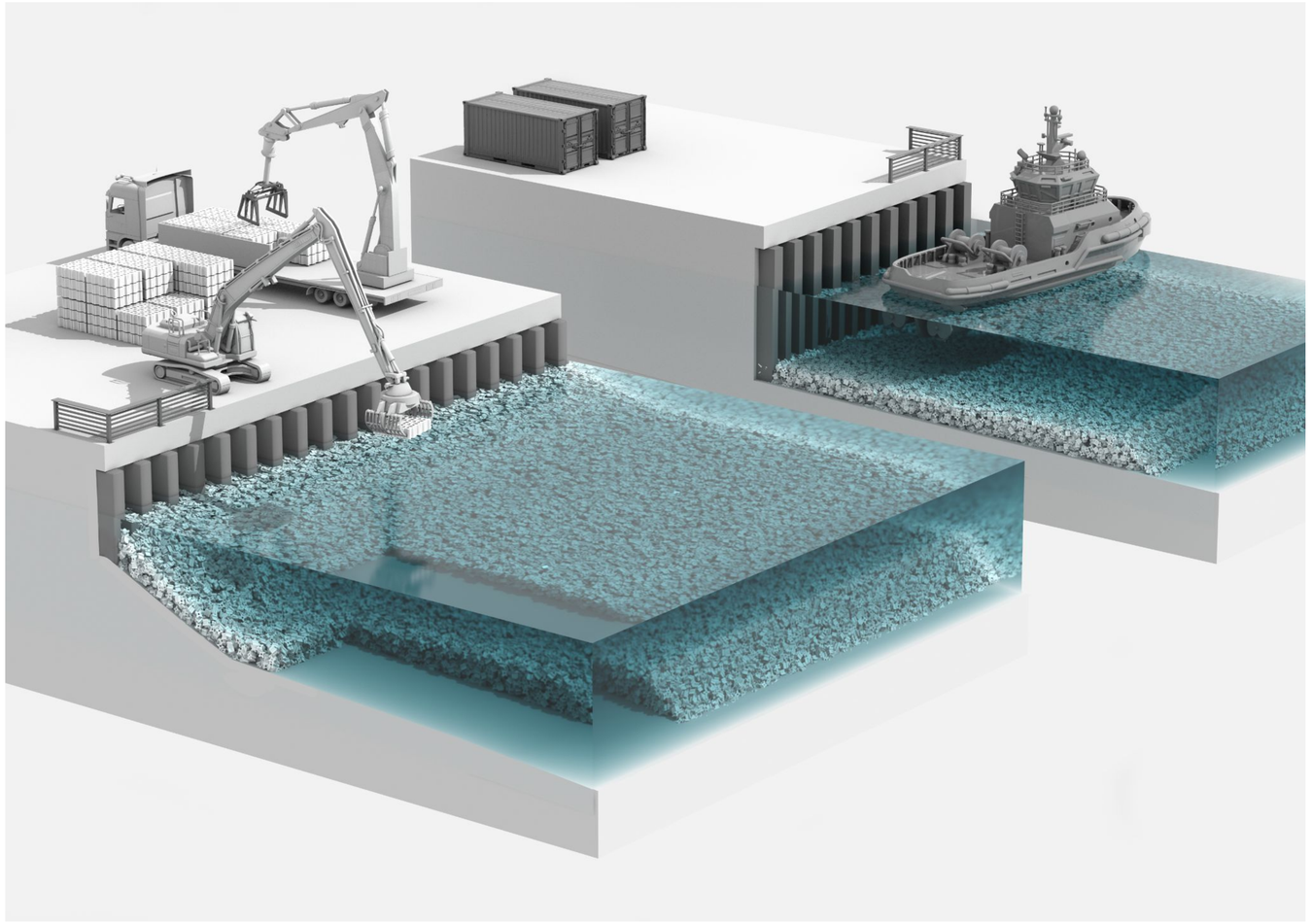


Installation of bottom (scour) protection
Xstone blocks can be installed flexibly to suit project conditions. Delivery is possible by truck, inland vessel using stone clamps, with temporary staging on the quay or directly on floating platforms. Blocks can be placed from the quay, from pontoons, or even by crane from vessels, depending on site access and water depth.

Placement is typically done with an excavator or crane equipped with a sorting gripper or stone clamp. The bottom profile is determined first, and blocks are installed per layer such that layer thickness is ensured as well as random orientation from the blocks.

To prevent spreading of the blocks, release the Xstones as close to the bottom as possible. Xstones behave similar to rock.

For initial application, a stone clamp or sorting gripper is preferred over hydraulic orange peel grabs to ensure minimum damage development. For re-use, an orange peel grab is required.



10.0 / INSTALLATION

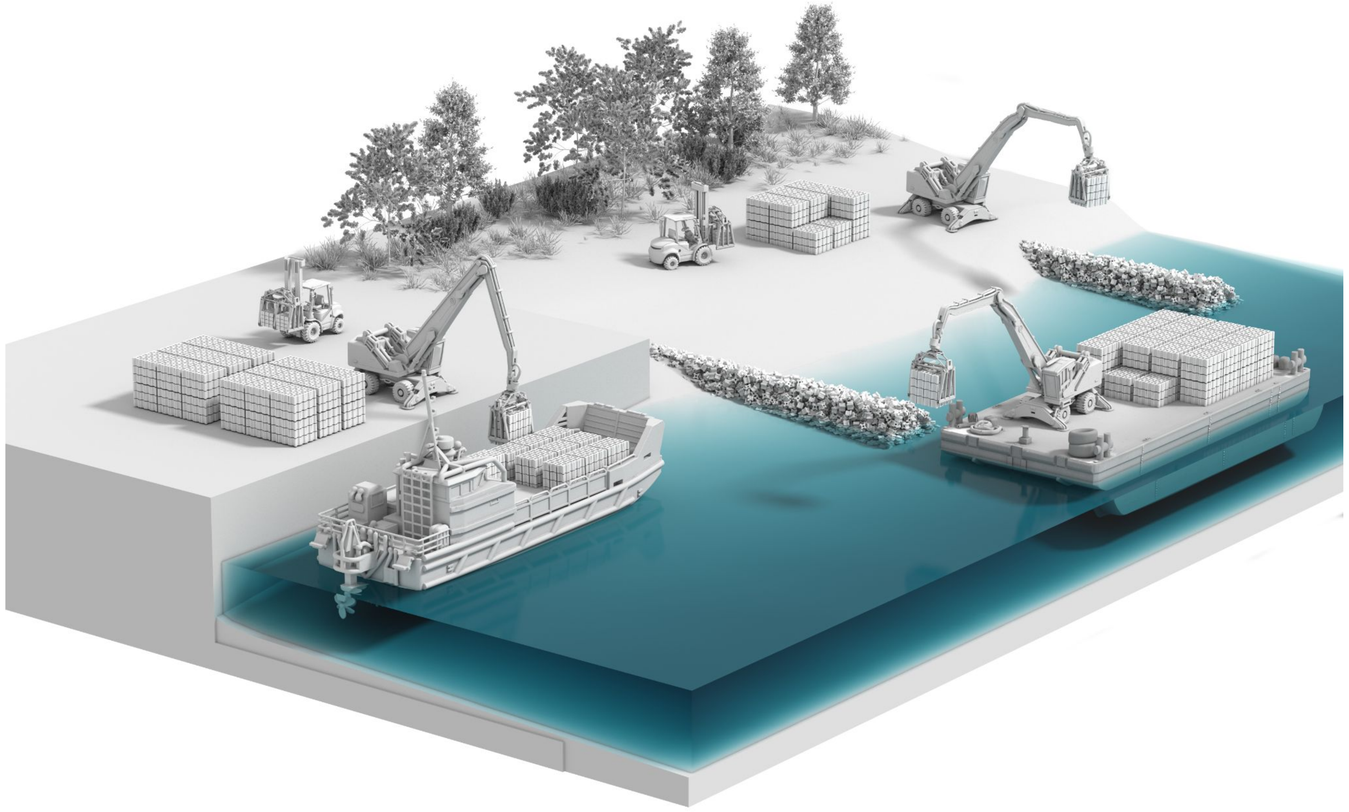
Floating equipment & Directly from vessel

Installation of hybrid land/water based structures
Xstone blocks can be installed flexibly to suit project conditions. Delivery is possible by truck, inland vessel using stone clamps, with temporary staging on the quay or directly on floating platforms. Blocks can be placed from the quay, from pontoons, or even by crane from vessels, depending on site access and water depth.

Installation is possible both from land and water, but preferably from water with pontoons using the up and out installation method. This ensures a 1:1 slope build-up and efficient construction.

For larger structures, entire packages can be placed at once to ensure high installation speed. Once the first layer is placed, the packages should be placed on top of the first layer to force random orientation.

For initial application, a stone clamp or sorting gripper is preferred over hydraulic orange peel grabs to ensure minimum damage development. For re-use, an orange peel grab is required.

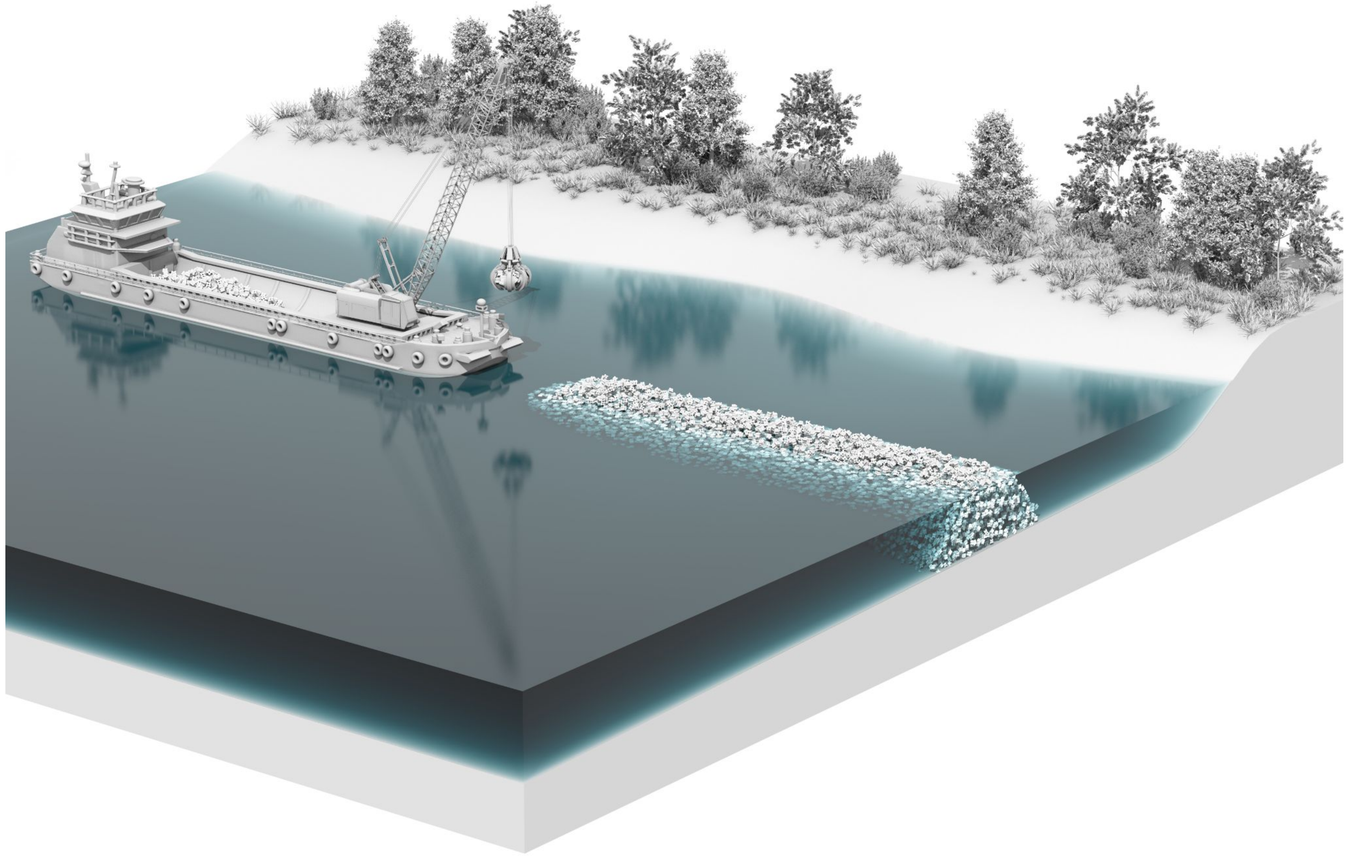


Installation of water based structures
In this situation, Xstone can be picked up from the factory location by inland vessel equipped with wire crane or other equipment placed on the ship. Xstone can then be installed directly from the water from the same vessel.

Installation is preferred using the up and out installation method. This ensures a 1:1 slope build-up and efficient construction.

Once the first layer is placed, the blocks should be placed on top of the first layer to force random orientation.

For initial application, a stone clamp or sorting gripper is preferred over hydraulic orange peel grabs to ensure minimum damage development. For re-use, an orange peel grab is required.



11.0 / HABITAT CREATION

Holcim bio-active concrete technology has plenty of benefits:

Adaptive surface texture and porosity	Specific surface microstructures that boost marine biodiversity
Low pH	pH lower than 10 (normal is 12-13) that boost marine colonization
Lower CO_2 footprint	CO_2 reduction reaching 41% compared with traditional (CEM I) concrete (Precast & RMX manufacturing)

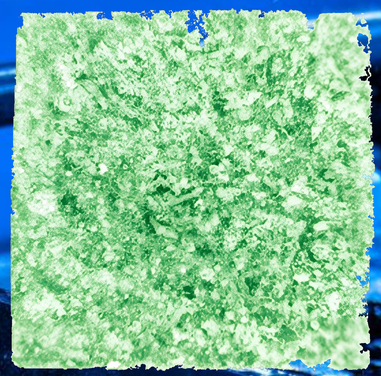


"Our concrete is designed to work with nature. It is CO_2-optimized and bio-active, helping plants and marine life settle naturally. The Xstone shape creates a safe place for life to grow, while the concrete itself supports that growth.

We can produce many types of concrete: standard, extra-heavy, porous, or even blocks with shells mixed in. Whatever the application, we can make the right solution."

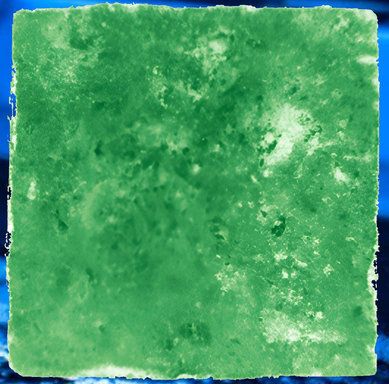
xstone

"Xstone creates the right conditions for diverse life to thrive naturally"

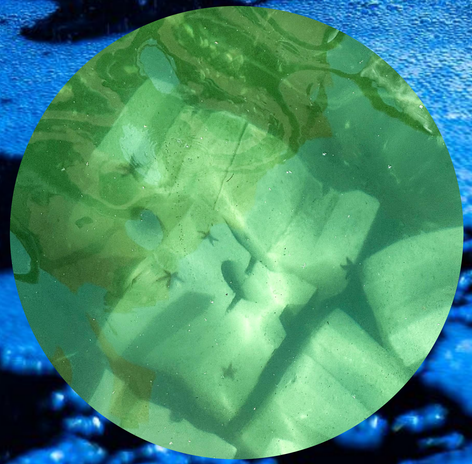


Natural stone

Bioreceptivity



Xstone



From installation to reef

In 3 months



HOLCIM

12.0 / ENVIRONMENTAL FOOTPRINT



DIT PRODUCT IS OPGENOMEN IN DE NATIONALE MILIEUDATABASE

The Xstone environmental footprint is verified and available on the Dutch National Environmental Database. EDPs are available upon request.

The following is taken into account for modelling the EPD:
A4, transport – 150km transportation by inland vessel
A5, installation – 33.2s excavator + 33.2s pontoon
B1, carbonation – modelled after EN16757
C1-C4 and D for regular card – 99% recycling, 1% landfill, 100yr
C1-C4 and D for re-use card – 50% re-use, 49% recycling, 1% landfill, 50yr

Type	MKI A1-A3 [€ per installed m^3 of construction]	MKI A-D [€ per installed m^3 of construction]	CO_2 A1-A3 [kg per installed m^3 of construction]	CO_2 A-D [kg per installed m^3 of construction]
Xstone s.g. 2.3	€4,42	€5,43	48,4	54,4
Xstone s.g. 2.3 re-use	€4,39	€3,40	48,1	32,7

13.0 / PHYSICAL MODEL TEST LOCATIONS



PROPELLER WASH BASIN

Can be used for:
- Bottom protection scour tests
- Quay wall scour tests
- Propeller wash stability

This facility can be rented as well

Properties
- 5.5 x 5.5m
- Water depth up to 1.2m
- 11”/13”/15” propellers with 11” pitch
- 2x 2k live video feed
- Flow meter available



WAVE FLUME

Can be used for:
- (floating) Breakwaters
- Scour protections
- Hydraulic stability
- Overtopping simulations

This facility can be rented as well

Properties
- 25 x 0.6 x 1.0m
- Water depth up to 0.70m
- H_s = 0.15m, H_{max} = 0.30m
- Flow meter available



FLOW FLUME

Can be used for:
- Filter Structure tests
- Flow over dams/groynes
- Flow parallel to dams/groynes
- Bottom protection scour tests

This facility can be rented as well

Properties
- 7.5 x 0.2 x 0.7m
- Water depth up to 0.56m
- 6 pumps, 0.4m/s depth averaged, 0.03m^3/s
- Flow meter available

14.0 / FUTURE DEVELOPMENTS

	Q1 2026	Q2 2026	Q3 2026	Q4 2026
Offshore wind scour protection • Stability tests in wave/current basin • Installation tests				
Bottom protection tests in propeller wash basin				
Construction of propeller wash basin version 2.0				
Revetment and toe structure stability tests (more parameters)				

15.0 / CONDITIONS OF USE

1. Holcim holds the rights to the presented photo and video material of Xstone. Use and distribution thereof is only permitted after obtaining prior permission from Holcim or an agreement with Holcim.
2. Holcim provides information regarding (the capabilities of) its product Xstone without obligation.
3. All information regarding Xstone provided (verbally or in writing) by or on behalf of Holcim is given in good faith but cannot be considered any guarantee by Holcim regarding the performance or suitability of the product. Holcim is not liable for the content thereof, not even towards third parties.
4. Holcim does not guarantee the achievement of the result that a user of Xstone wishes to realize with the aid of Xstone, even if advice from Holcim related to the use of the products with a view to that result.
5. The party creating or having designs created for the use of Xstone is itself responsible for conducting tests and verifications.
6. If, at any time prior to, during, or after the conclusion of an agreement, advice of any nature has been provided by Holcim regarding the use of Xstone, such advice shall form part of the agreement in question and shall have meaning and legal effect in the relationship between the parties only if such advice has been provided in writing and the other party owes Holcim an agreed separate fee for it.
7. Holcim is not liable for any damage arising from the use of the product information provided by Holcim. Designs made with Xstone are always the exclusive responsibility of the designer. Holcim recommends testing these designs with physical models.
8. The relationship between Holcim and the recipient of the product information is governed exclusively by Dutch law.

16.0 / PICTURE MATERIAL



Propeller wash basin test



Xstone as bottom protection



Offshore wind scour protection tests at Deltares

1:1 slopes are built with ease!



Contact us:

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Q4 2026
Holcim Coastal