Arcadis & ReefSystems

Questions from Arcadis:

1. What is your experience with tender processes? Do you have demonstrable experience in increasing the chances of winning offshore projects by deploying your solution?

In recent years we have seen a transition towards nature-inclusive construction projects. We frequently get approached by energy suppliers, contractors, project developers, architectural firms, etc. In the past year, ReefSystems concepts contributed to the winning of at least two tenders. For the Lauwersmeerdijk project, 'nature-inclusive' was an important pillar for the award of the project.

2. If the system is used in international projects, how are transport costs and the transport of elements arranged?

MOSES modules can be produced in a local concrete factory (see question 15) or they can be transported efficiently from the Netherlands. Per 20ft container, 825 modules can be transported on a ship, divided over 11 pallets. The pallets can be trucked from the local port to the reef location for assembly. Transport from Rotterdam to Colombia is possible.

3. Is there already experience in Latin America?

Yes, a reef monitoring project (funded by Boskalis) is now running in Portobelo, Panama, where several reefs have been installed in collaboration with Reef-2-Reef Panama to experience the workability of each system and research the effect on the local ecosystem. This research is still ongoing, but several findings have already been communicated:

- MOSES was the most preferred system to work with due to its manageability and modular system
- MOSES attracts the most marine life due to the great diversity of microhabitats and high 3D complexity compared to the other reefs

Here some pictures of MOSES in Portobelo, Panama:





The photos above show the option to create different microhabitats are by placing 'dividers'. This allows a wide variety of species to find a suitable hiding place in the reef.

4. Is the system stable under extreme wave conditions

In December 2021, stability tests were performed at the independent knowledge institute for applied research in the field of water and subsurface Deltares. Several extreme conditions were tested (1:20 scale), under which the MOSES-reefs remained stable. The collected data is currently being progressed.

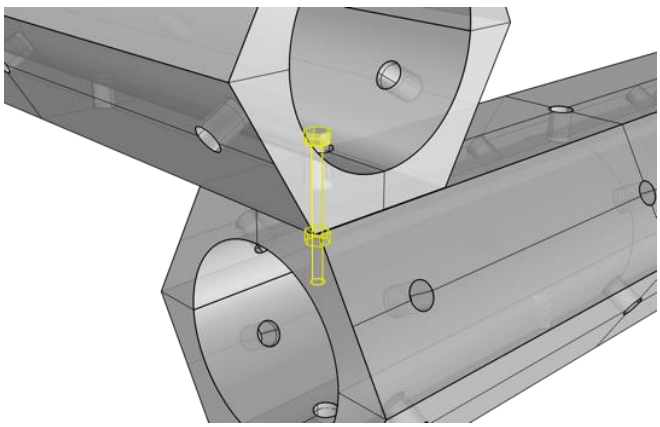
This video shows one of the tests, which corresponds to the conditions in San Andres:

Conditions (1:20 scale):
- *Water depth: 18 cm (3.6 meters)*
- *Max. wave height: 9 - 10 cm (1.8 – 2m)*
- *Period : 1.12 - 1.25 second*

To create extra weight, the lower modules can be produced closed or with a thicker wall. Various anchoring mechanisms can be attached to the Stelcon plates to create more stability.

5. How are the systems attached?

The system is mounted on standard 2mx2m stelcon plates with chemical anchors (m10 – m18). The modules are attached to each other with bolts and nuts (stainless steel 316), which ensures a strong mutual connection that does not perish underwater.



How long does it take?

For the project as shown in the photos above, 300 modules were build up divided over 6 stelcon plates with 2 people in 2 working days (16 hours). This can be done in a harbor or the on beach, where after the reefs can be transported to the final location with a small boat and lifting balloons or with a crane vessel.

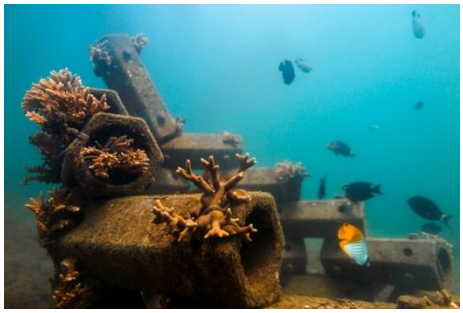
For the installation in San Andres, Colombia, the following applications may be used:

- Building reefs on Stelcon plates 200X200X14CM
- Anchoring reefs with JDL folding anchors (more info in this link)
- Erosion mats

6. What is the success rate of reef systems?

MOSES is used as substrate on which corals, seaweed, anemones, mussels and oysters can grow. Fish, crustaceans and shellfish can find food, shelter and breeding grounds in and between the modules. Wageningen University & Research (WUR) has shown that MOSES is successful in stimulating biodiversity and population growth. To accelerate the positive effect on the ecosystem, we often collaborate with local research and diving organizations. For example, in Kenya, small pieces of coral (Corals of opportunity) are grown in coral nurseries, where after the are attached to the structures. These corals are now successfully growing on the structures and will take over the artificial reef in a few years.

Here some pictures of MOSES in Shimoni, Kenya (3 months after installation):

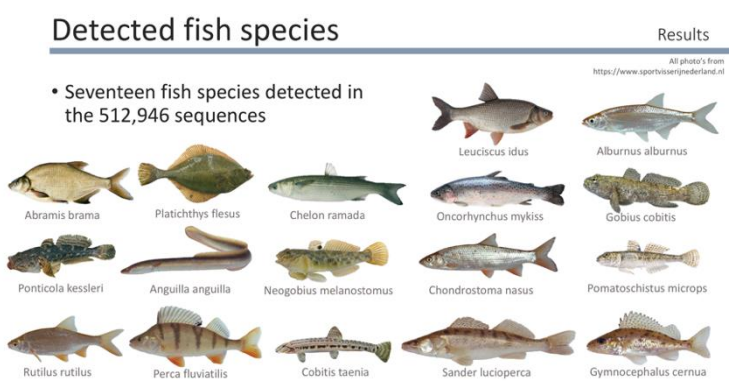




Here some photos of MOSES in Haringvliet, the Netherlands (1 year after installation):



7. How much experience do they already have with long-term projects and how do they monitor the success (communities, remote sensing, surveys, etc.?)

The first reef installations in the Netherlands have been installed in collaboration with WUR to measure the effectiveness on the ecosystem. By eDNA monitoring techniques have identified the following fish species in and around the reef:



A senior ecologist from WUR visually confirmed these species while taking the eDNA samples:

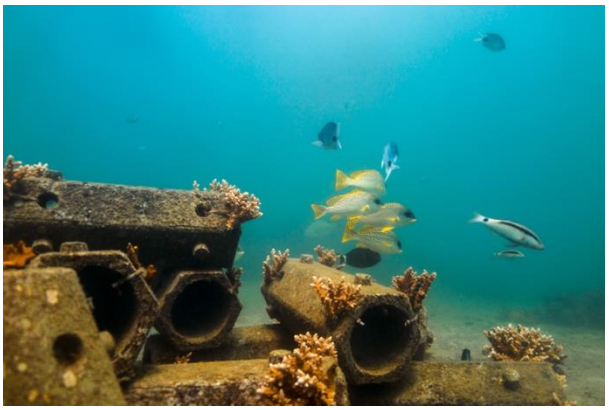
- *Japanese oysters*
- *Barnacles*
- *Starfish*
- *Colony-forming sea squirts (Botryllus violaceus)*
- *Moss animals (several species)*
- *North Sea crab*
- *Velvet swimming crabs*
- *Beach Crabs*
- *Brush Scratches*
- *Sturgeon shrimp*
- *Various red seaweed, green seaweed and brown seaweed, such as sea lettuce and Japanese berry seaweed.*

8. What are possible negative effects on the environment, flora and fauna?

This statement by a Professor of Ecology of Marine Animals at WUR describes that MOSES has no negative effects on the local ecosystem. Arcadis consulted a senior ecologist for the Lauwersmeerdijk project and he concluded the following: *''Various small species such as worms and benthic animals live in the Wadden Sea. These may be adversely affected by the placement of the elements. This negative effect does not outweigh the expected positive effect for the other biological quality elements."* For more information, see Explanation of Water Permit for the Natural Transition pilot (Lauwersmeerdijk) - D10031351 from Arcadis.

9. Is data known/available on settlement success of corals on the structures?

The PH value of the modules is neutral to seawater. This makes the settlement of corals successful. This was tested for the first time in Kenya. Small coral fragments are placed on the structures after installation to kickstart the reef restoration. The photos below show the same structure. On the left photo small coral fragments have just been placed on the structures (October, 2021). The photo on the right shows the same structure 3 months later (January, 2022). Researchers from WUR have indicated that the artificial reef will be fully overgrown in a couple of years (see project here).




10. Are there different sizes of the tubes? If so, can these be combined on a structure?

With a modular system it is necessary that all tubes are identical. We could produce molds to increase the size of the MOSES modules, but this will mean you lose the advantage of building up the reefs by hand, which keeps transport and construction costs low.

11. What is the lifetime of the blocks?

Blast furnace cement with fiberglass reinforcement is extremely suitable for installation in seawater. The modules continue to harden after installation and the growth of corals on the structure also provides reinforcement. This allows the structures to last 500+ years.

12. Can the structures withstand bio-eroding organisms?

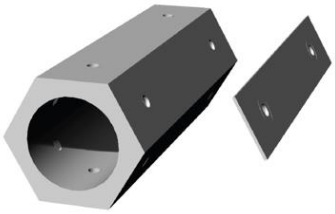
This does not affect the structures.

13. Are there potentially harmful substances in the cement that can leak out and end up in nature?

This statement by a Professor of Marine Animal Ecology at Wageningen University and Research describes that MOSES has no negative effect on the local ecosystem.

14. **Can different substrate types be used in addition to blast furnace cement?**

Other cement types can be used. However we advise the use of blast furnace cement due to the low CO2 emissions of this product. Furthermore, by attaching 'plates' with cultivated coral larvae on them, other substrate shapes can be applied (see image). These plates can be attached to the modules after installation.



15. ***What are the consequences for communities in terms of fishing or tourism?***

The installation of this eco-breakwater will increase fish populations and create a very interesting reef for divers. This will greatly increase diving tourism, which will also benefit the local population.

16. **Where are the elements manufactured? Can this also be done locally?**

The elements are currently produced in the Netherlands. However, MOSES modules can be produced locally with minimal resources. For the proposed project in San Andres, Colombia we advise to produce the modules locally. This would:

- Lower overall project costs
- Lower CO2 emissions (less transport)
- Create local employment
- Create awareness and willingness to cooperate through community involvement

ReefSystems can contribute to this project:

- Contributing knowledge and ideas for efficient production and installation of reefs
- Exporting molds, materials and other necessities to San Andres, Colombia for local production
- Setting up local production facility for production of modules
- Guiding reef construction and providing advice in development of installation plan

17. **What range of cost price (per m2 or ha) should I think about? What are the determining factors?**

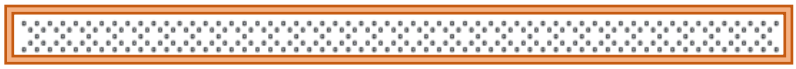
Based on the information provided by Arcadis we propose the following plan:

Artificial MOSES-reefs as ecological enhancing solution for coastal erosion in San Andres, Colombia

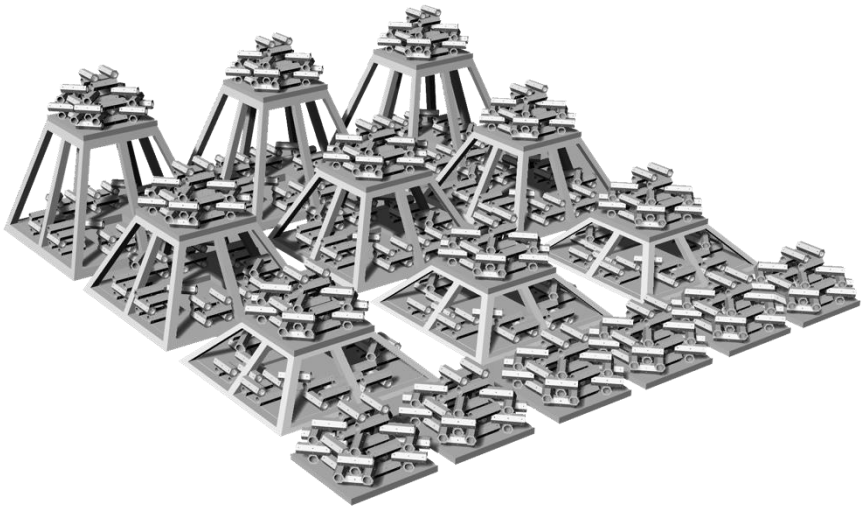
In a previous study Spratt Bight beach on the north side of the island San Andres in Colombia has been identified as an island that suffers from coastal erosion. This forms a threat to the local population, infrastructure and tourism sector on the island. By building a nature-inclusive submerged breakwater with MOSES modules the following effect can be reached:

- Reduce incoming wave power to stabilize Spratt Bight beach and prevent coastal erosion
- Increase beach profile with 8 – 15 meters
- Elevate beach with +/- 1 – 3 meters
- Create habitats for increased biodiversity and marine populations
- Create hard substrate for corals to grow on to restore the health of local ecosystem
- Create diving hotspot, which positively effects tourism and economy in San Andres
- Create local employment to stimulate economy

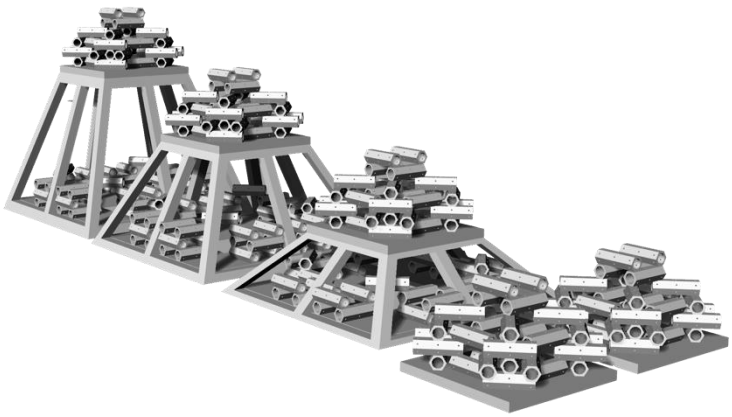
Estimated surface for reef installation:

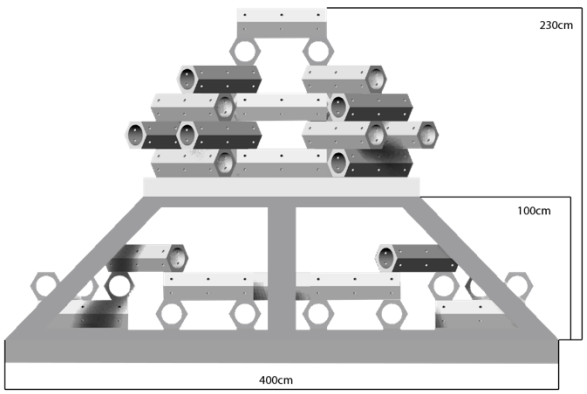


- 750 meters wide
- 17 meters long
- Various heights
- Different reef designs to reduce wave power and coastal erosion

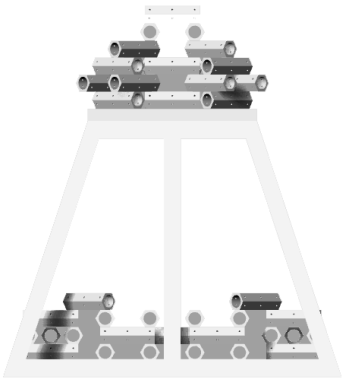


- The reefs have various heights to effectively reduce wave power
- Pyramids have a flatpack design for efficient transport
- Configuration of reefs as shown on the left is an example. Final design needs to determined based on further research

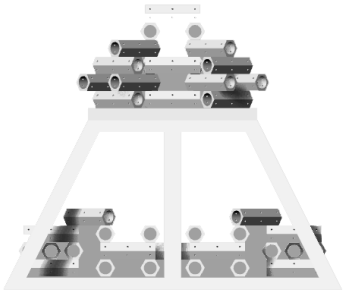




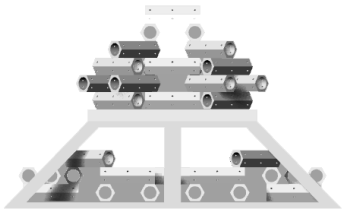
Reef C



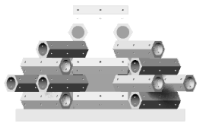
Reef A



Reef B



Reef C



Reef D

- *Reef A, B and C consist out of flat pack designed pyramids (for efficient transport) and 100 MOSES modules*
- *Reef D consists out of standard stelcon plate (200x200x14) and 50 MOSES modules*
- *1 segment consists out of Reef A (1x), Reef B (1x), Reef C (1x), Reef D (2x)*
- *1 segment contains 400 MOSES modules*
- *1 segment is approx. 17 meters long and 6 meters wide*
- *Total reef (750m x 17m) consists out of approx. 125 segments*
- *Total reef consists out of approx. 50.000 MOSES modules, 375 frames of various heights and 250 stelcon plates*

For the calculations below we assume:

- 400 molds needed for production of 400 modules per day
- Material costs: €10 per module
- Average costs per flatpack pyramid: €3.500 (*estimation*)
- 50.000 modules needed for this project
- 12 employees produce 400 modules per day (50.000 modules produced in 125 months)
- 1 employee costs €2.000 per month (Colombia)
- 12 employees build 1 segment in 1 day (all reefs build on land in 125 days)

	Unit	Amount	Costs per unit	Total
Molds for production of MOSES modules	Mold	400	€ 150	€ 60.000
Materials for MOSES production	Material	50.000	€ 10	€ 500.000
Bolts and nuts Stainless steel (316) for reef construction	Bold + nut (316 quality)	100.000	€ 0,5	€ 50.000
Flat pack pyramids (Reef A, B & C)	Pyramid	375	€ 2.500	€ 937.500
Stelcon plates (Reef D)	Stelcon plates	250	€ 100	€ 25.000
Loan payment €2.000 per month for 12 employees	Months work for 12 employees	12	€ 24.000	€ 288.000
ReefSystems royalties	Per module	50.000	€ 4	€ 200.000
			Total costs for reef with various heights (750m x 17m):	**€ 2.060.500**

These calculations do not take into account:

- Transportaton costs
- Import costs of materials & molds for production (tax exemption requests to local authorities possible)
- Installation & anchoring costs
- Costs for detailed safety calculations

Installation of reefs can be done by building up reefs close to shore and lifting them into the water with a crane.

By attaching lifting balloons to the structure the reefs can be dragged to their final destination, where after they can be carefully placed.

By using lifting bags there is no need for heavy machinery or big installation vessels. This enables the local community to install the reefs and it results in low installation costs.

Final comments

There is a great need from the Thirteen Overseas Countries and Territories (OCTs) that are associated with the European Union to restore the marine ecosystem in this area. We are currently in the final phase of a funding applications through RESEMBID (min. budget €300.000 – max. budget €1.5 million). This is through a collaboration with WUR and Aruba National Park Foundation to install reefs along the coast of Aruba. This is one of many options to find funding for this project.