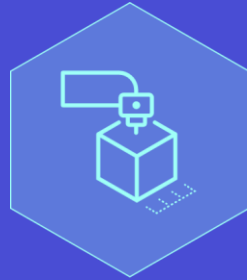


Pilot site & testing

3D printed maritime caisson prototypes



Qing Zhang, Holcim
Jose Carlos Jimenez TECNALIA

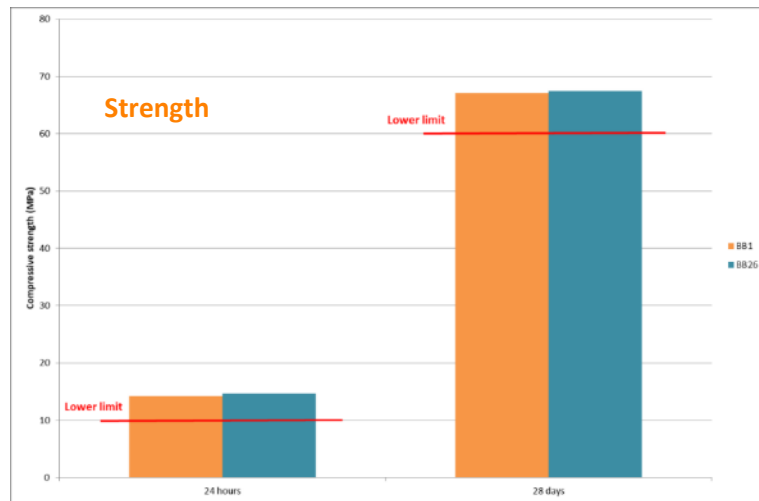
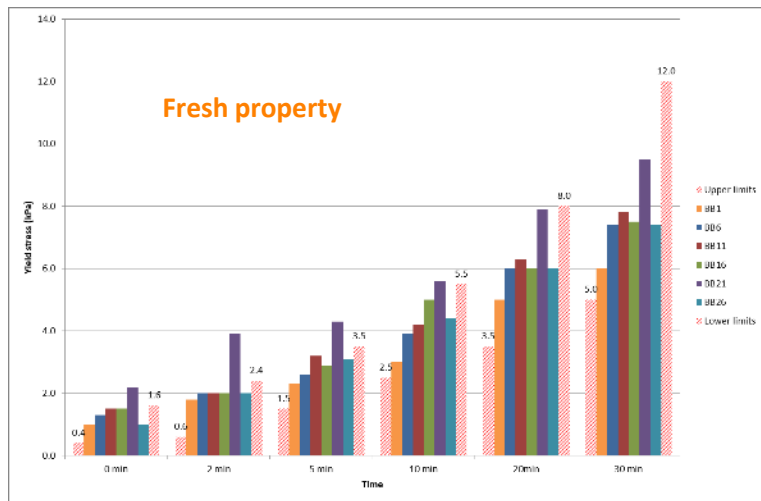
Maritime Construction



- Validation of the characterization of the constructive impression material both from the chemical point of view and from the point of view of the rheological-temperature control in a specific production plant.
- Printing tests of caisson-type structural elements specially optimized for additive manufacturing with specifically designed crane-robotic systems.
- Testing of underwater construction elements development favouring marine life development, following the methodology developed in T6.4.
- Testing in two different locations (indoor/outdoor) additive manufacturing processes with mortars using robotic systems in vertical structures, also favouring positive environmental impacts on the marine ecosystem

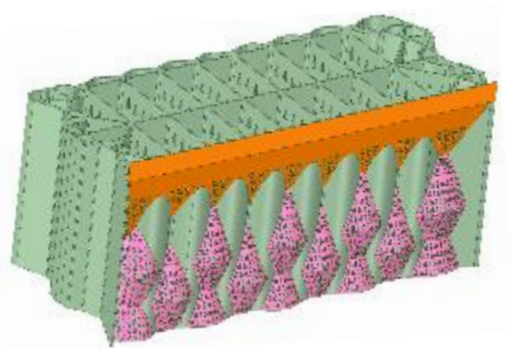
Material Production Trial & QC

Production Trial in France: Consistent premix quality, despite minor batch variations manageable on-site, is verified through rheological and mechanical testing to meet strength and performance criteria



Test Plan for Maritime Use Case 7.5

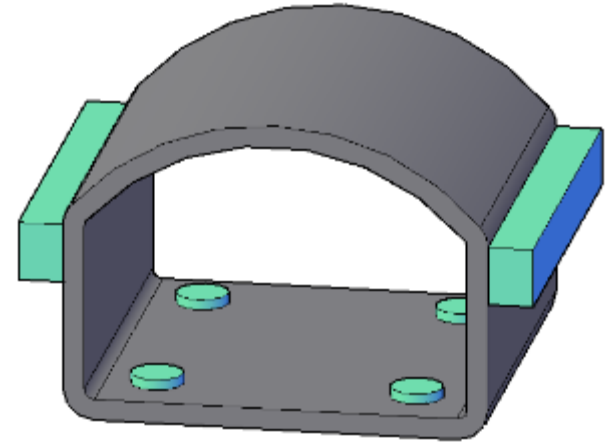
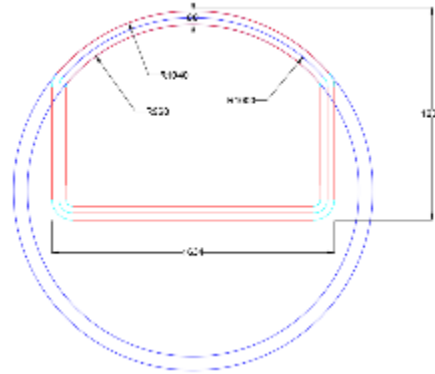
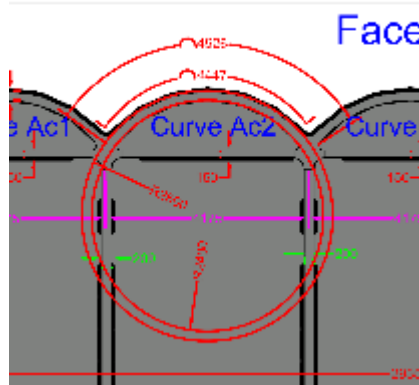
- Two scale down prototypes and their perspective tests:



-  Submersion and 6-month monitoring for bio-walls to validate the bio-diversity promotive function
-  Structural test on critical elements to validate the resistance and ductility

Structural Prototype Design

Proposal to allow construction or reduce Steel reinforcement: Test representative element, proving enough strength and ductility of the element between layers.



Grey=> V=0,568 m³

Structural Prototype Production

5 repeats of structural prototype were manufactured in June 2025 by COBOD. 3 of them Will be tested.



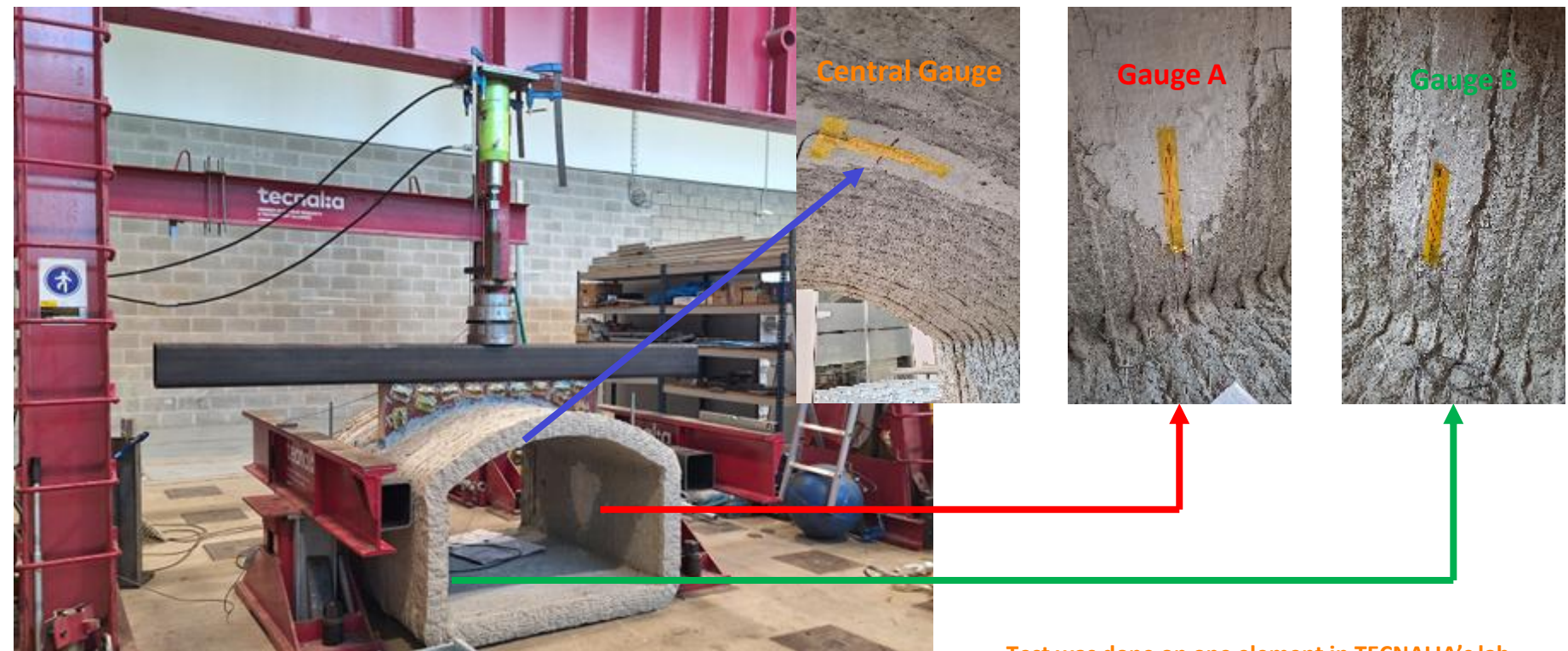
Structural Testing

Test 3 repeats of representative element, to prove enough strength and ductility of the element between layers.



Tecnia's structural laboratory

Test Set Up

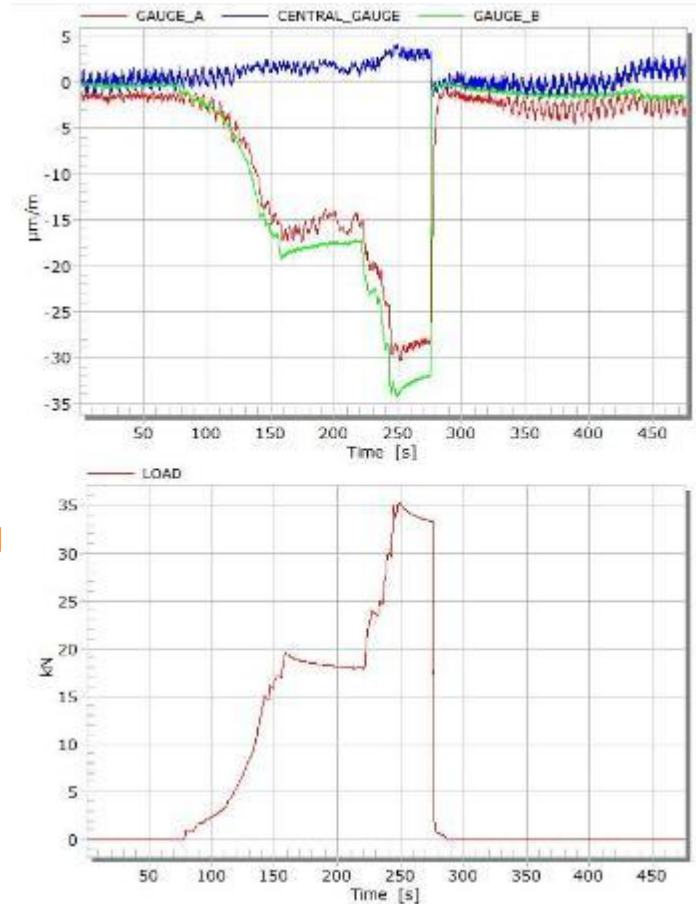


Test was done on one element in TECNALIA's lab.

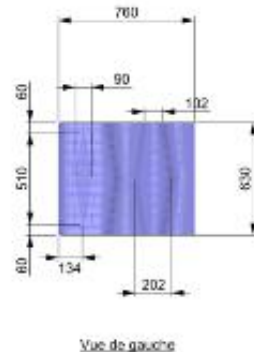
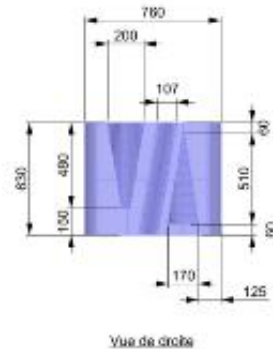
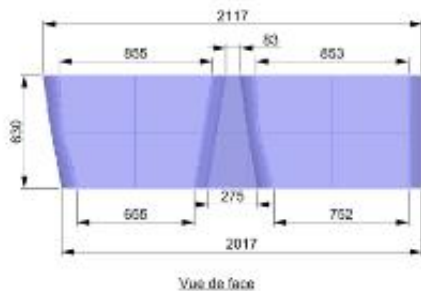
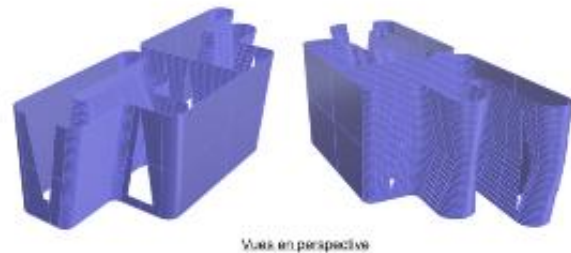
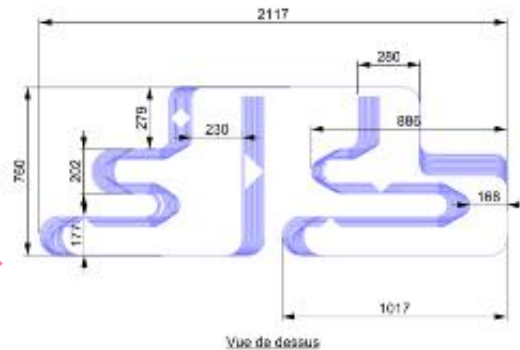
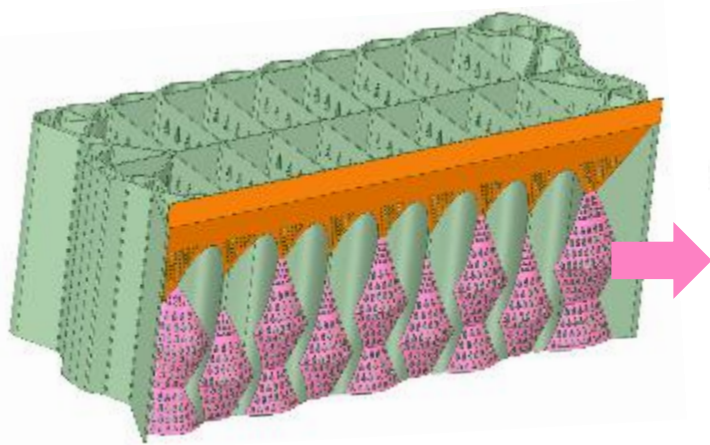
Structural Test Result

Conclusion of the structural test: The prototypes successfully achieved the design load of 15 Tons while remaining in the elastic regime.

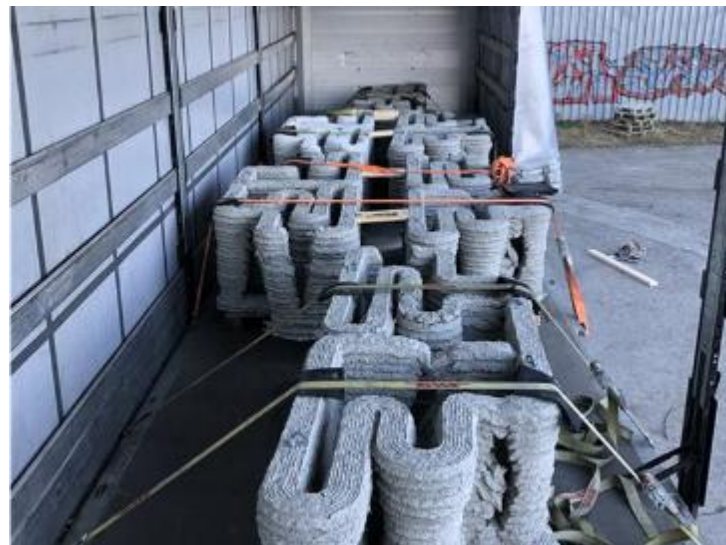
- Element 1 (loaded to 21 Tons): Lateral restriction and non-homogeneous support led to premature cracking at 40 μ strain.
- Element 2 (loaded to 25 Tons): Optimal performance reached with lateral freedom and distributed support; achieved peak compression (280 μ strain) without damage or cracking.
- Element 3 (loaded to 22 Tons): Lateral freedom and distributed support allowed high traction (200 μ strain) though the element reached its elastic limit and transitioned into non-linear behavior.



Bio-Wall Prototype Design



Bio-Wall Production by COBOD



Five bio-wall units were successfully manufactured, featuring integrated anchorage to simplify handling for transport and submersion.

Bio-Wall Monitoring at Gijon



- 1 marine environment : Northeast Atlantic Ocean
- 1 pilot sites : Gijon (Spain)
- 1 station : ~200 m
- 5 sites : ~10 m with a distance of 20m
- 1 depth / elevation : 12m
- 1 orientation : Vertical
- 2 materials : 3DPC bio-receptive, reference concrete
- 5 replicates per material
- 3 photoquadrats 25 x 25 cm per structure
- 2 monitoring after 2 months and after 9 months of submersion



1st monitoring campaign

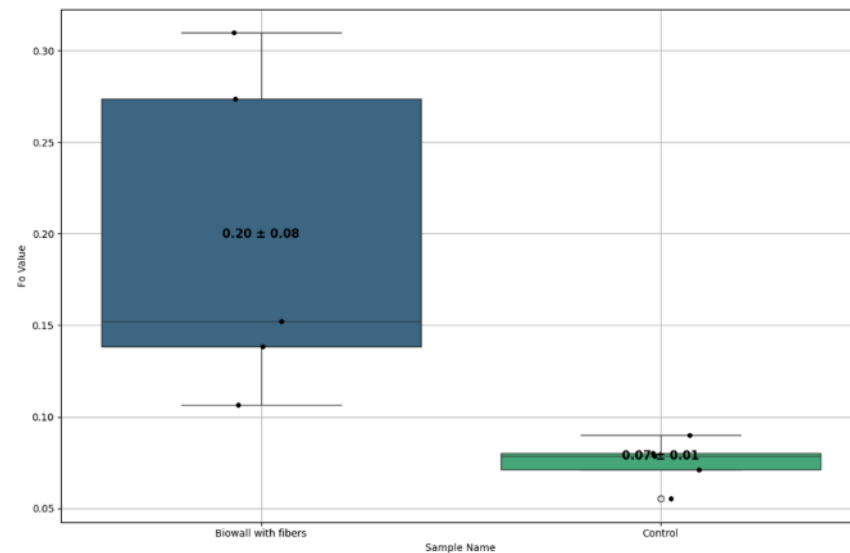
- Gijon 02/09/25 : Two dives
- All protocols conducted underwater with success
- Analysis ongoing



In-situ Materials performance



Significant higher biomass on 3DPC material compared with reference concrete:



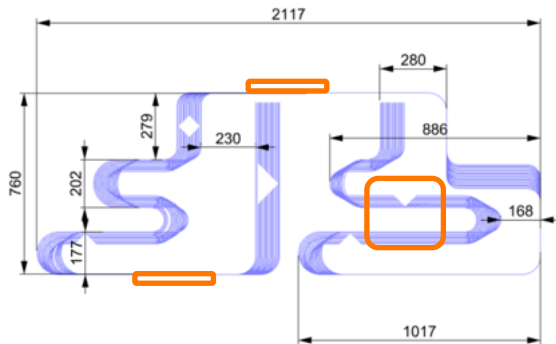
Bio-wall vs Reference

Significant faster marine life development for bio-wall



Photoquadrats

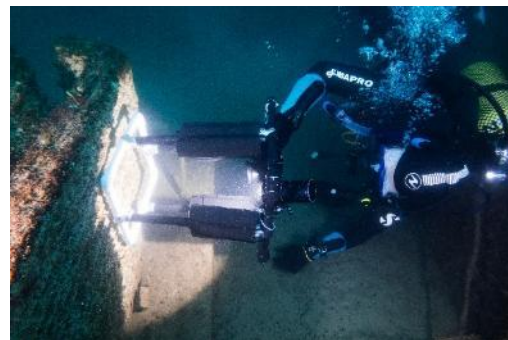
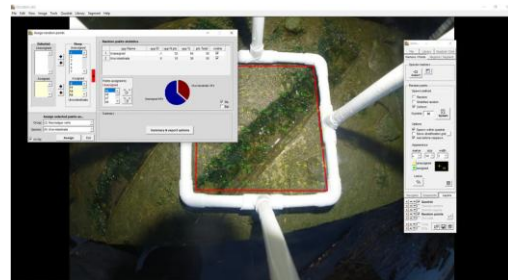
- 2 orientations : vertical / horizontal
- 3 per structure: one on the top and one on each side
- Total of 3x10 photoquadrats = 30 photoquadrats
- Analysed in the lab with photoquad
- Monitored indices: speed, surface cover, abundance, equitability, % occurrences, diversity, limiting invasive species



Biowall

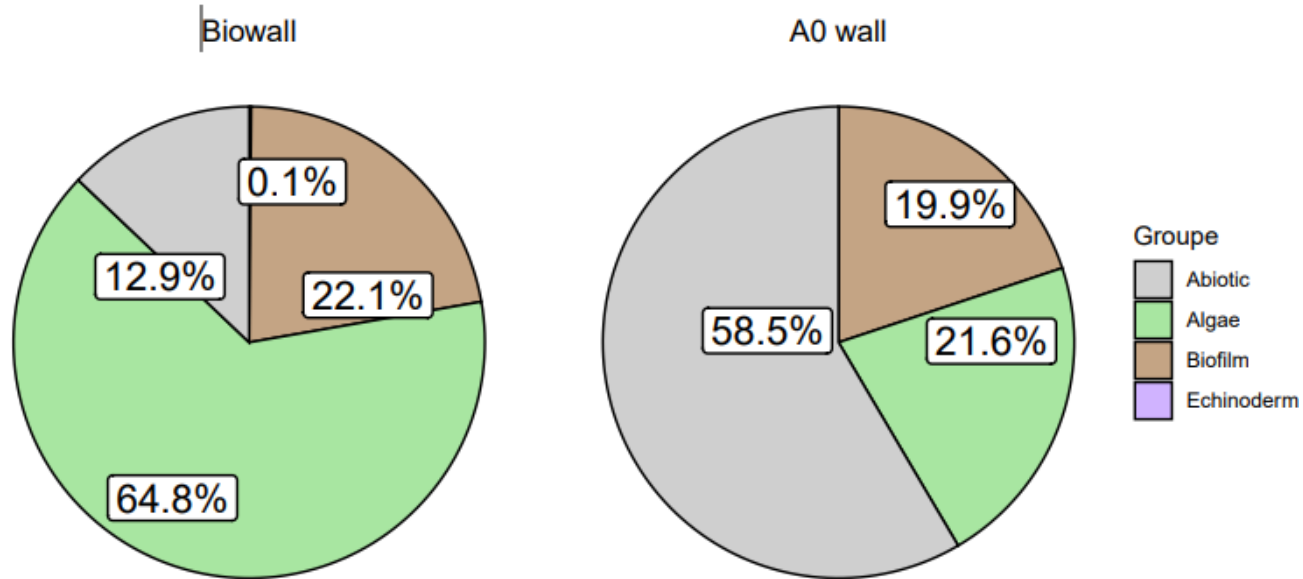


Reference wall

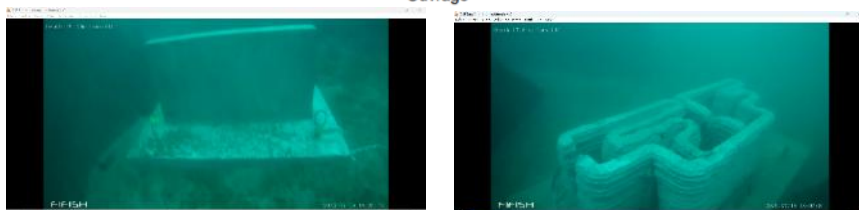
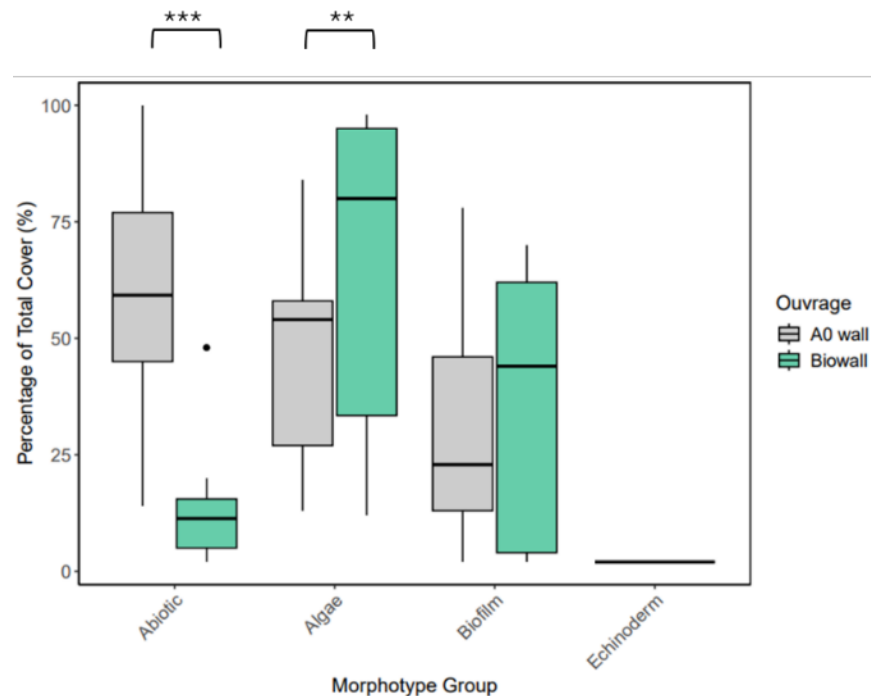
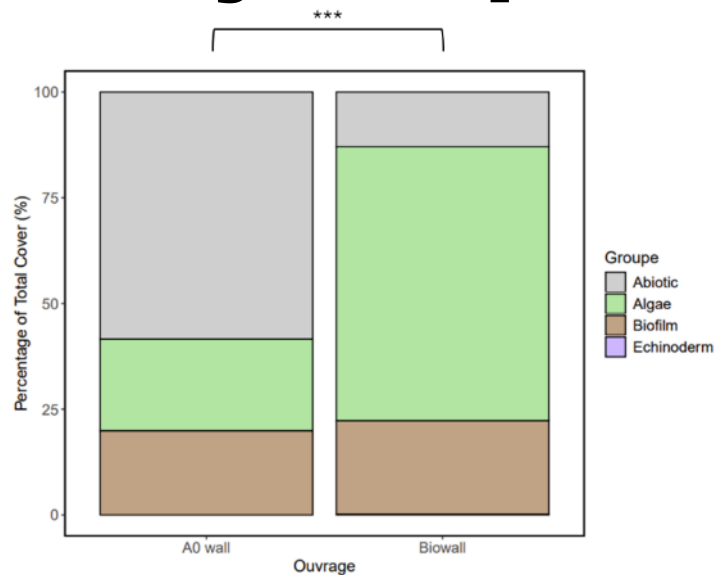


Colonization by sessile species

More algae present and more biotic cover on Biowalls

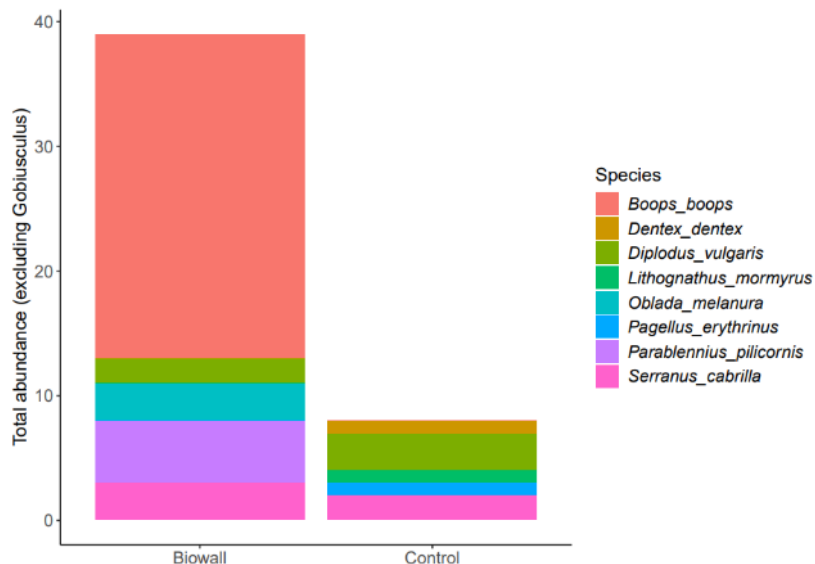


Community Composition

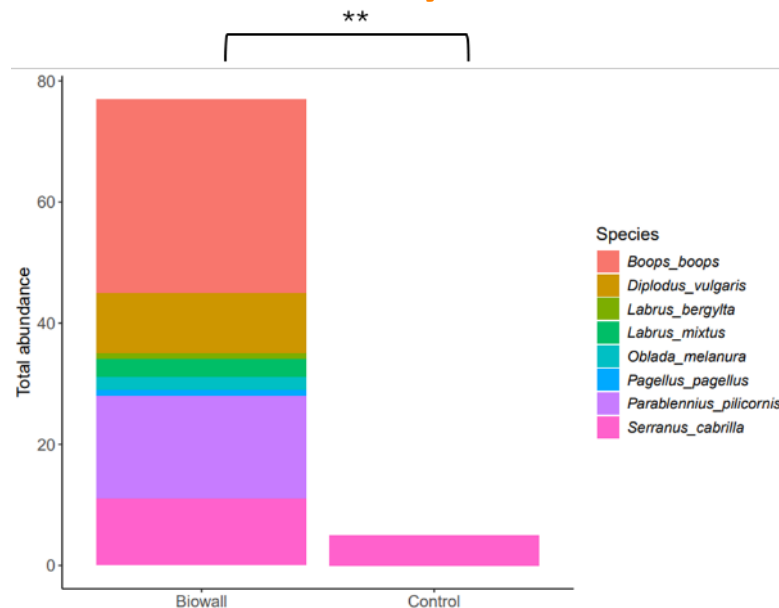


Higher species richness and abundance

Video analysis



Dive count analysis



Transforming Maritime Construction with 3DCP

Conclusion:

- The caisson design and manufacturing strategy successfully demonstrated:
 - **Material Efficiency:** Over **40% reduction** in total concrete and steel consumption.
 - **Carbon Leadership:** A **53% lower CO2 footprint** (A1-A3) compared to conventional methods.
 - **Economic Advantage:** Total production cost savings of up to **46%**.
- Structural tests confirm that the innovative fiber-reinforced design eliminates the need for extra steel rebar. A pragmatic pathway for industrial adoption lies in a hybrid reinforcement strategy: while fibers handle primary loads, 3D-printed sections can serve as lost formwork for vertical rebars.
- In-situ monitoring validates that our 3D-printed "Bio-walls" significantly boost bioreceptivity, creating ready-to-deploy solutions for artificial reefs and coastal restoration

A Mature Path Forward: The project has proven the technical and economic feasibility of automated maritime construction. We look for collaboration opportunities to mature this technology for full-scale commercial deployment.