Structural analysis of a concrete floating platform: Ensuring tank water-tightness under extreme events

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BERIDI'S PLATFORM: FLOWIN FLOATER

- Concrete hexagonal shape
- Supports the IEA 22MW wind turbine (Reference)

Ensure water-tightness

↓

No reversal moment in perimeter walls of non-flooded cells

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Part of the section always in compression

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No pre-tensioning of the concrete is required

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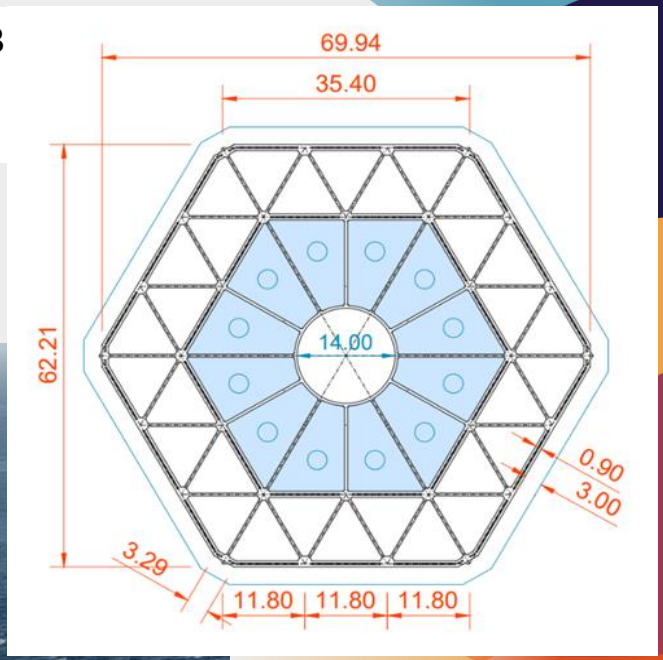
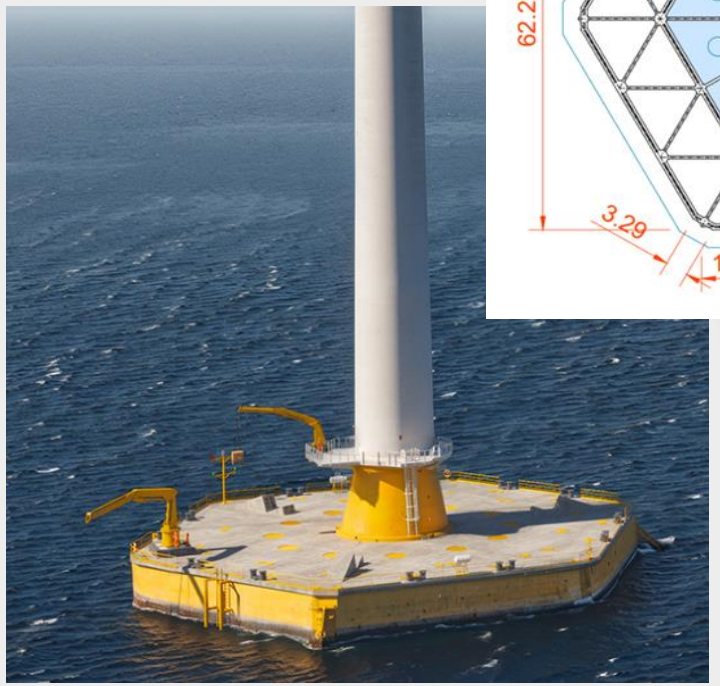
Highly cost-efficient structure

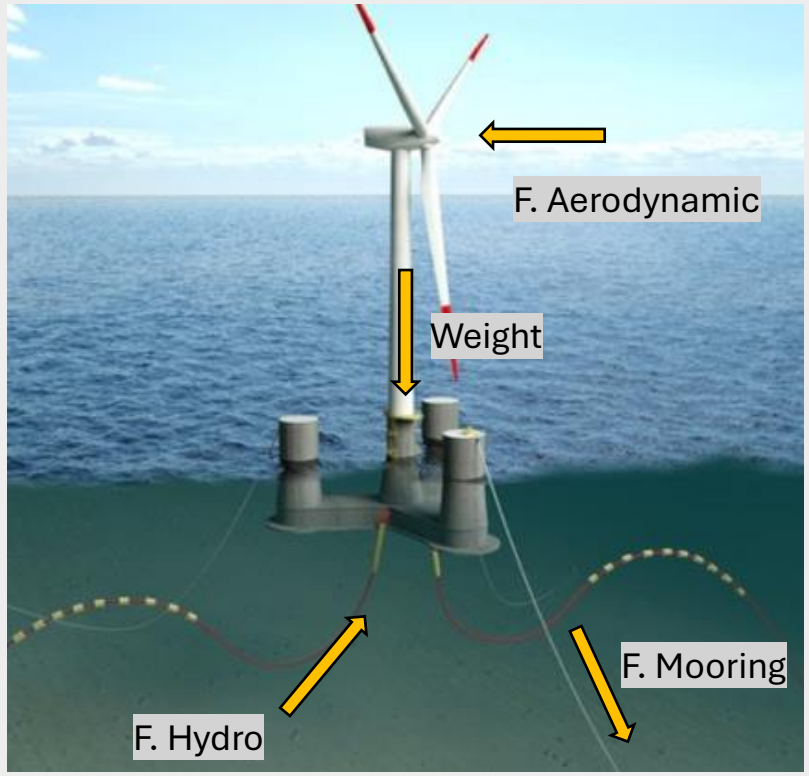
CONCRETE VOLUME = 12,564m3
STRUCTURE WEIGHT = 31,410t
DRAFT = 15,09m

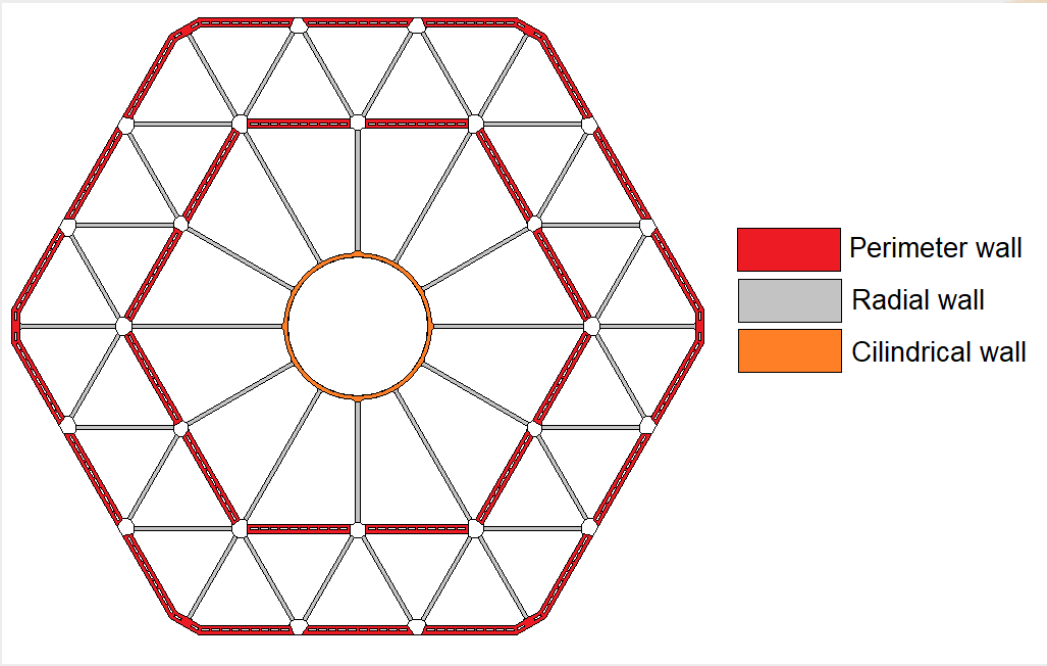




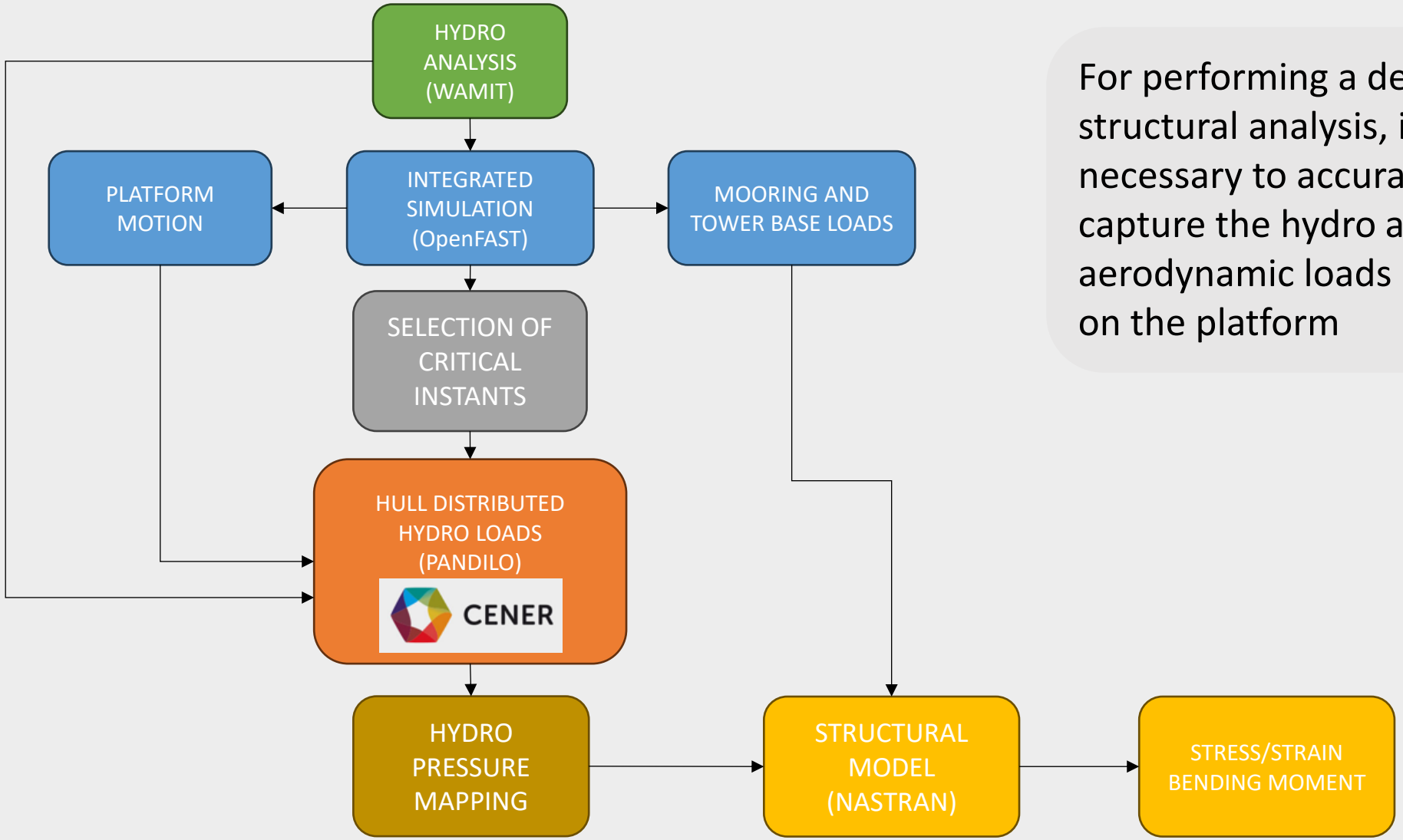
OBJECTIVES

- Analyse the performance of the platform under the combined action of the hydrodynamic pressures, mooring line tensions and tower base loads.
- Verify that no reversal moment occurs in the perimeter walls of the non-flooded cells





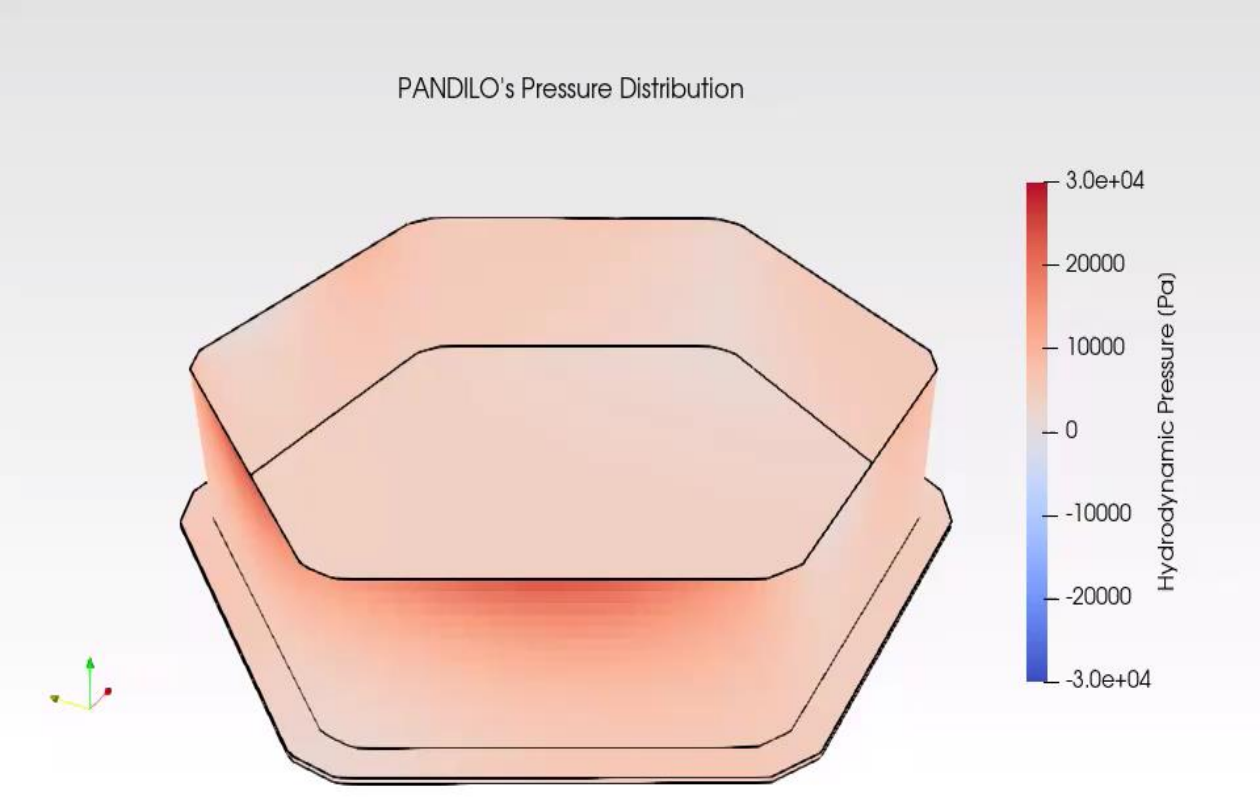
METHODOLOGY



For performing a detailed structural analysis, it is necessary to accurately capture the hydro and aerodynamic loads acting on the platform

DISTRIBUTED HYDRO PRESSURES

- PANDILO (Panel Distributed Loads): CENER's in-house tool
- Maps hydro pressures on the hull in time domain
- It is based on linear potential theory
- Currently implementing 2nd order effects
- PANDILO post-processes DLC results obtained through integrated simulations
- Very efficient computationally



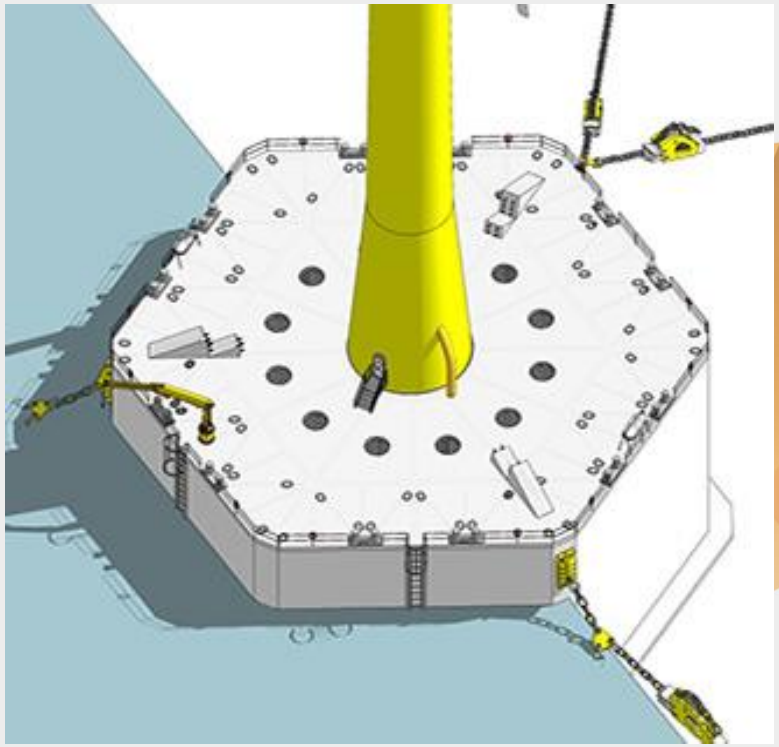
STRUCTURAL ANALYSIS

Structural calculations are performed by standard FE methodology

Linear static analysis

Critical instants considered:

DLC 1.6			DLC 6.1	
Criteria	Time step (s)		Criteria	Time step (s)
Max Line 1 tension	554.0		Max Line 1 tension	5861.6
Max Line 2 tension	4149.3		Max Line 2 tension	5861.6
Max Line 3 tension	6161.6		Max Line 3 tension	10259.5
Max Line 4 tension	512.3		Max Line 4 tension	5908.7
Max Line 5 tension	512.0		Max Line 5 tension	5908.7
Max Line 6 tension	1081.0		Max Line 6 tension	8871.5
Max Hydrodynamic My	5465.5		Max Hydrodynamic My	5668.1
Min Hydrodynamic My	591.0		Min Hydrodynamic My	5659.8
Max Tower Base My	4148.7		Max Tower Base My	5659.2
Min Tower Base My	8992.1		Min Tower Base My	8869.0
Max Hydrodynamic Fx	2363.9		Max Hydrodynamic Fx	5652.9
Min Hydrodynamic Fx	3425.1		Min Hydrodynamic Fx	444.6

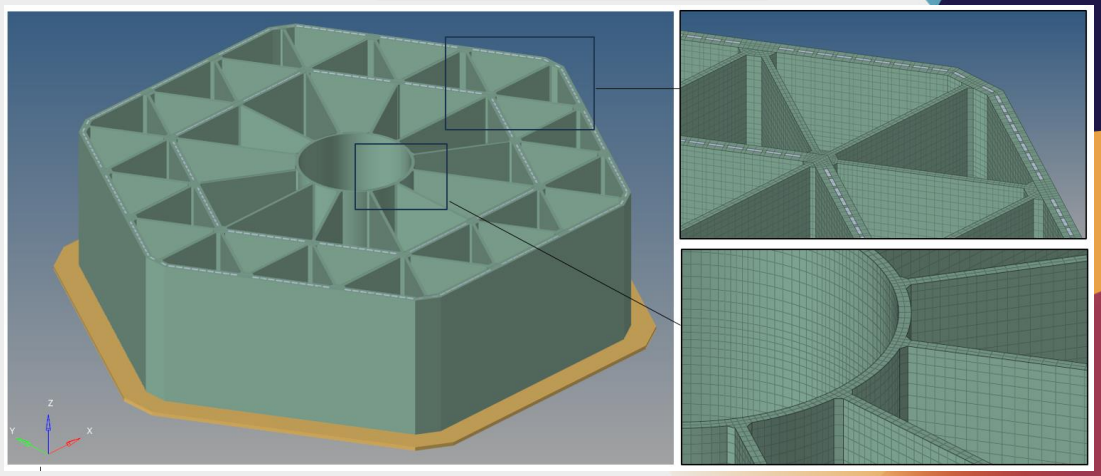


STRUCTURAL ANALYSIS

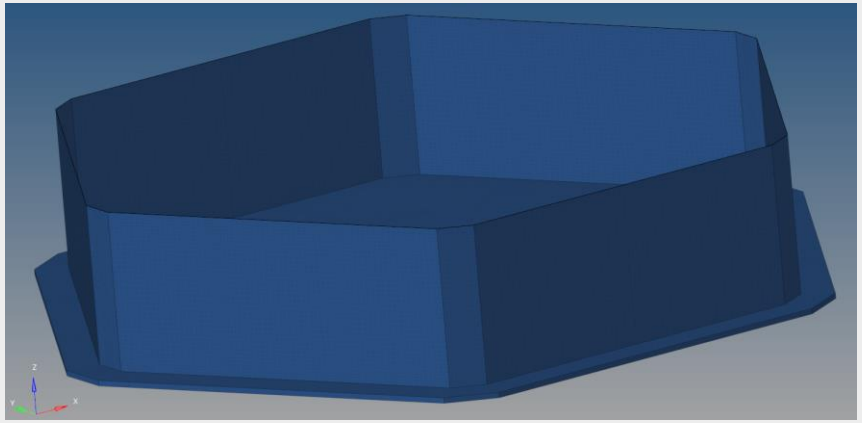
FE model:

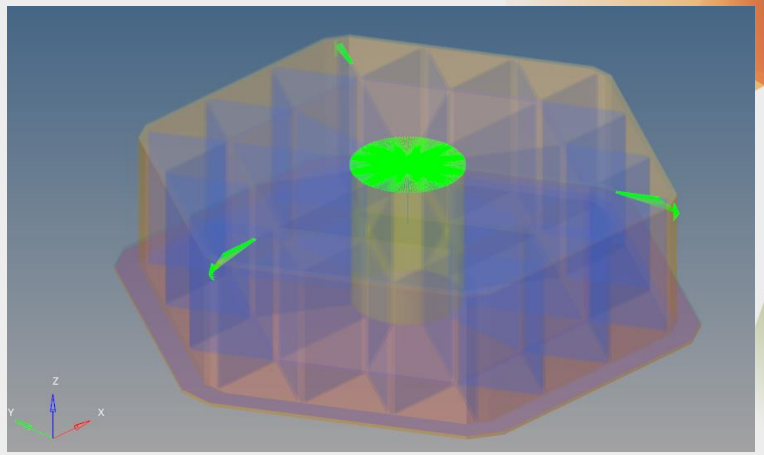
- Based on platform's geometry provided by BERIDI
- 3D elements for concrete structure
- 2D for steel reinforcement
- Link for mooring and tower fixing solutions

Structural mesh



Hydrodynamic mesh



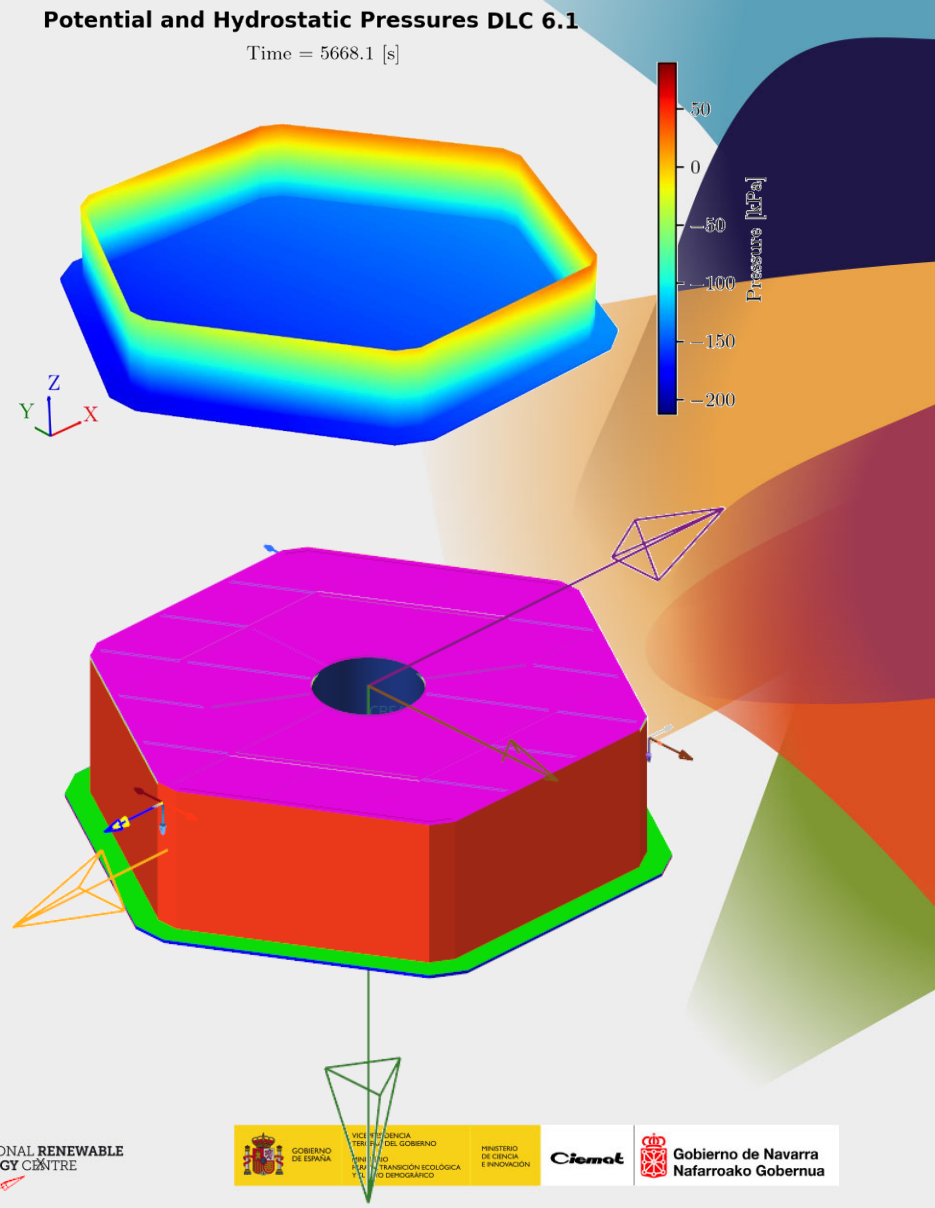


STRUCTURAL ANALYSIS

Boundary conditions and loads

- Pressures on the hull surface obtained from the hydrodynamic + hydrostatic analysis
- Hydrostatic pressures on the flooded cells
- Forces produced by the mooring lines
- Forces on tower base

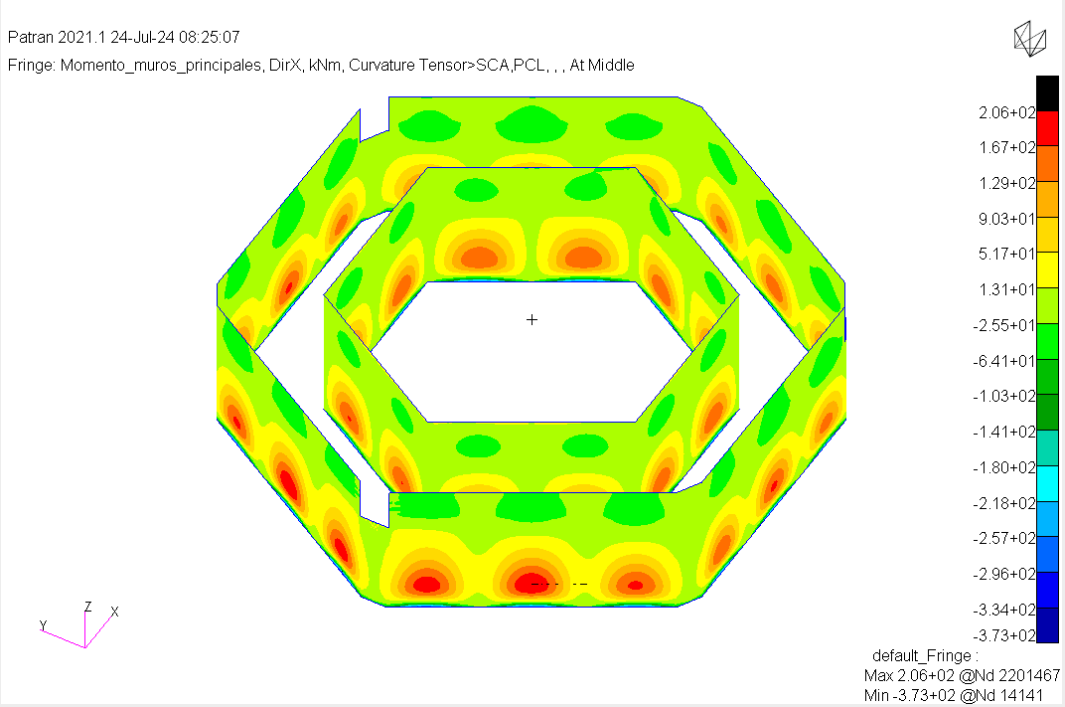
Inertia Relief to balance the system of forces on the structure.



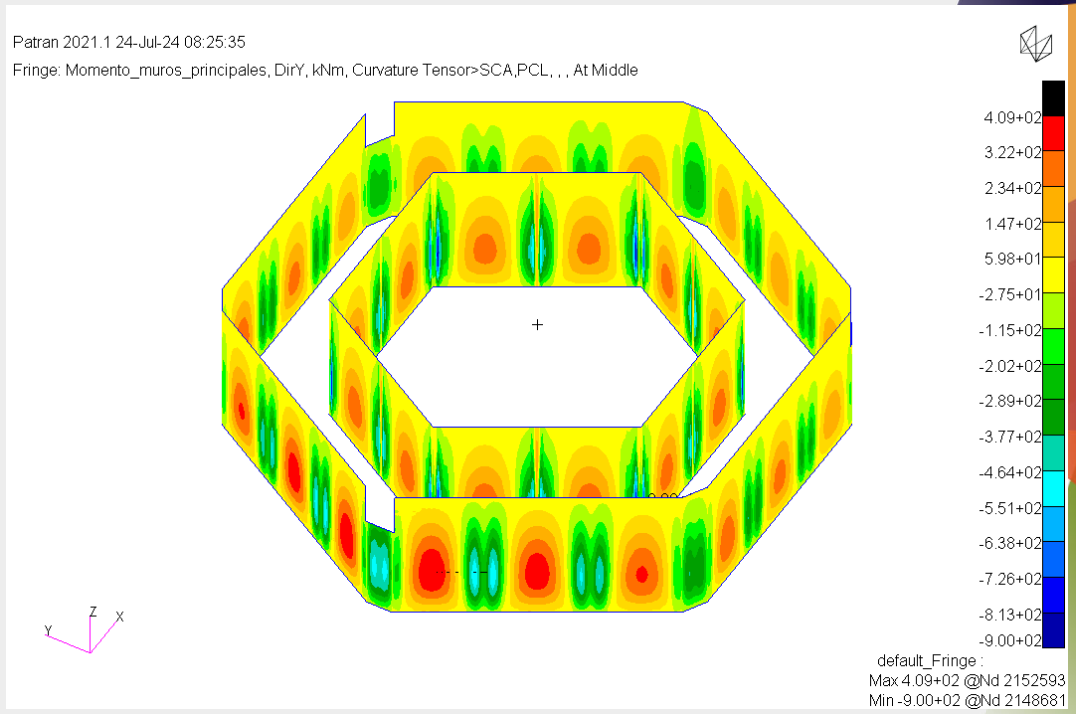
RESULTS

Bending moment distribution on perimeter walls

- Bending moment map close to the strain distribution map



Bending moment [kNm], horizontal direction, perimeter walls. DLC6.1_Max_HydroMy

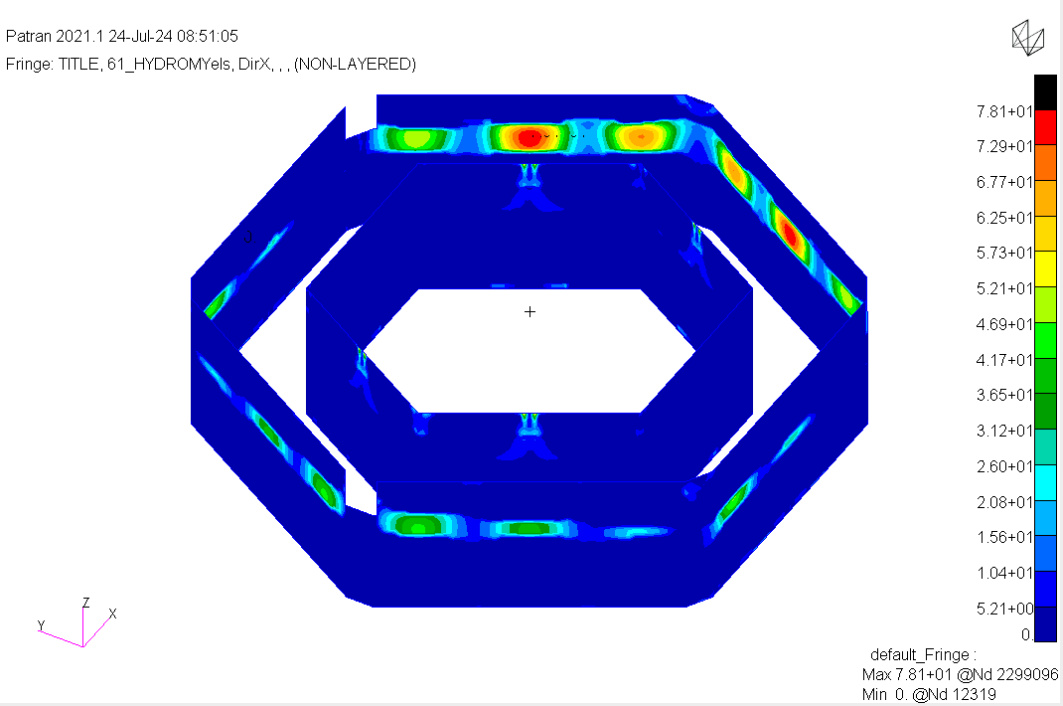


Bending moment [kNm], vertical direction, perimeter walls. DLC6.1_Max_HydroMy

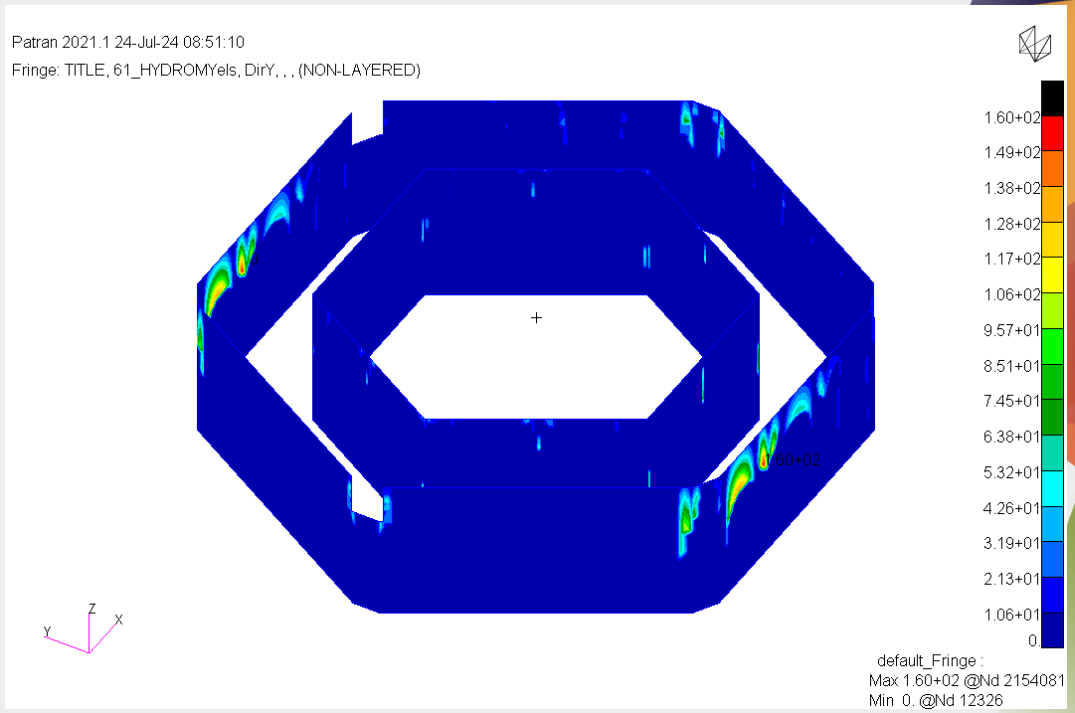
RESULTS

Bending moment differences on perimeter walls

- Areas with change of sign in the upper region of outer perimeter wall



Bending moment difference [kNm], horizontal direction. DLC6.1_HydroMy

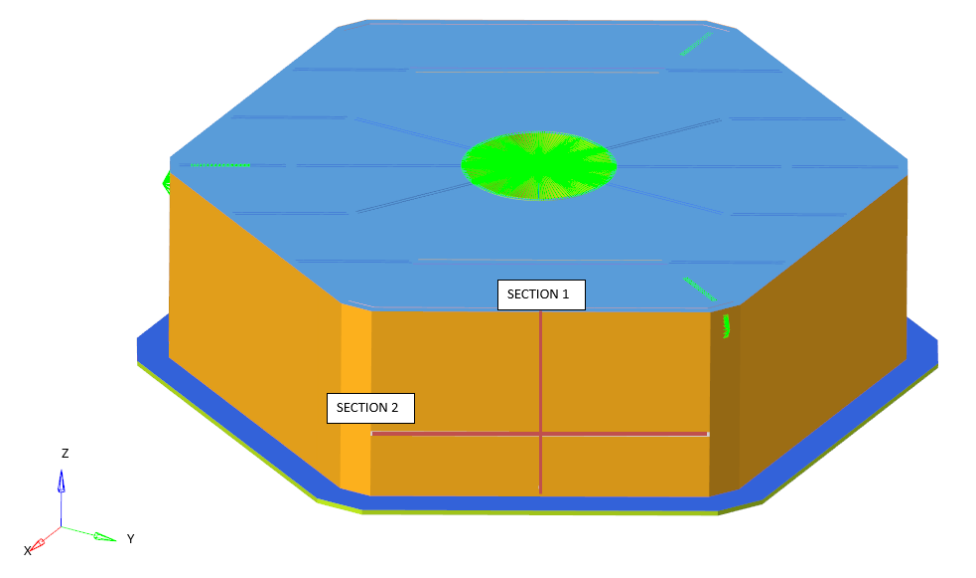


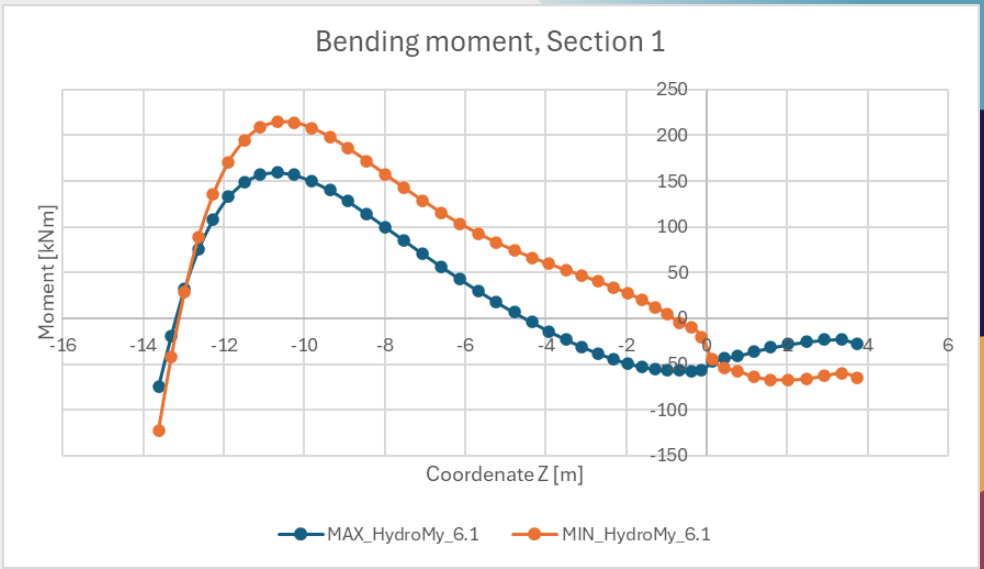
Bending moment difference [kNm], vertical direction. DLC6.1_HydroMy

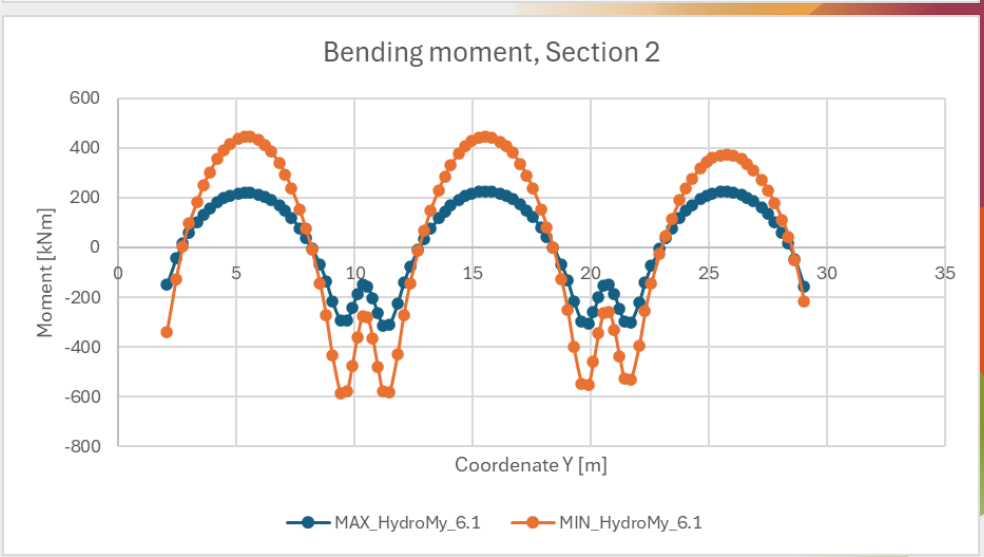
RESULTS

Bending moment diagram

- Bending law varies in magnitude but not in working direction
- Sections with a change of sign are those close to the zero-moment. It is not expecting concrete cracking
- No inversion moment in sections with higher bending moment



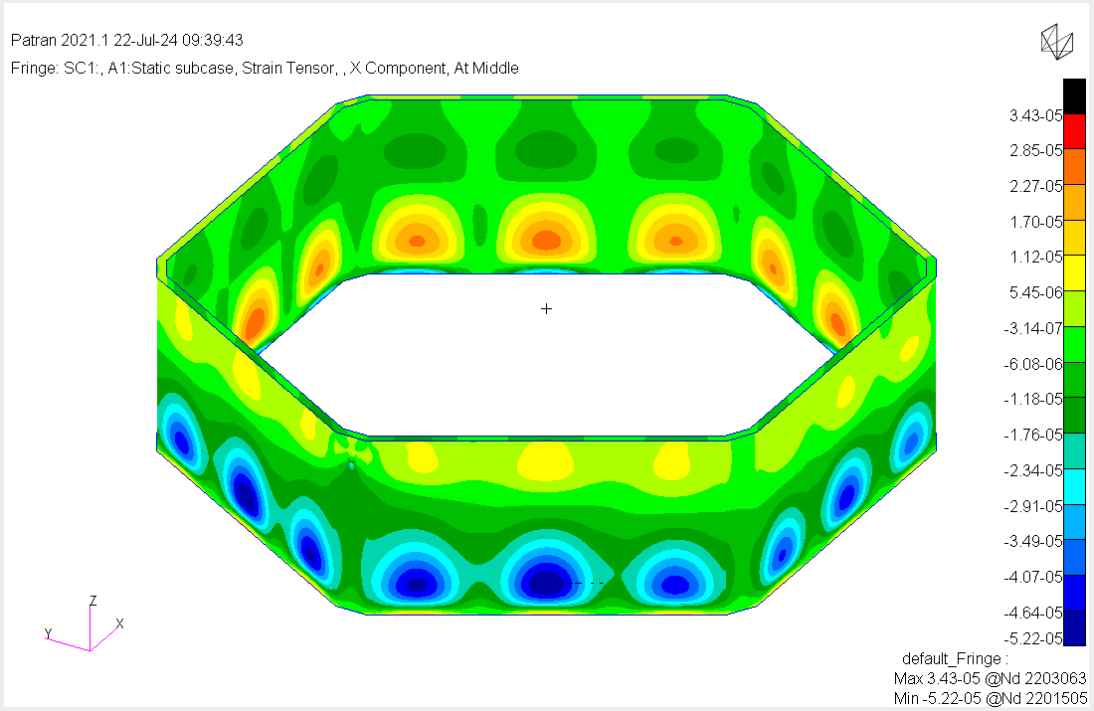




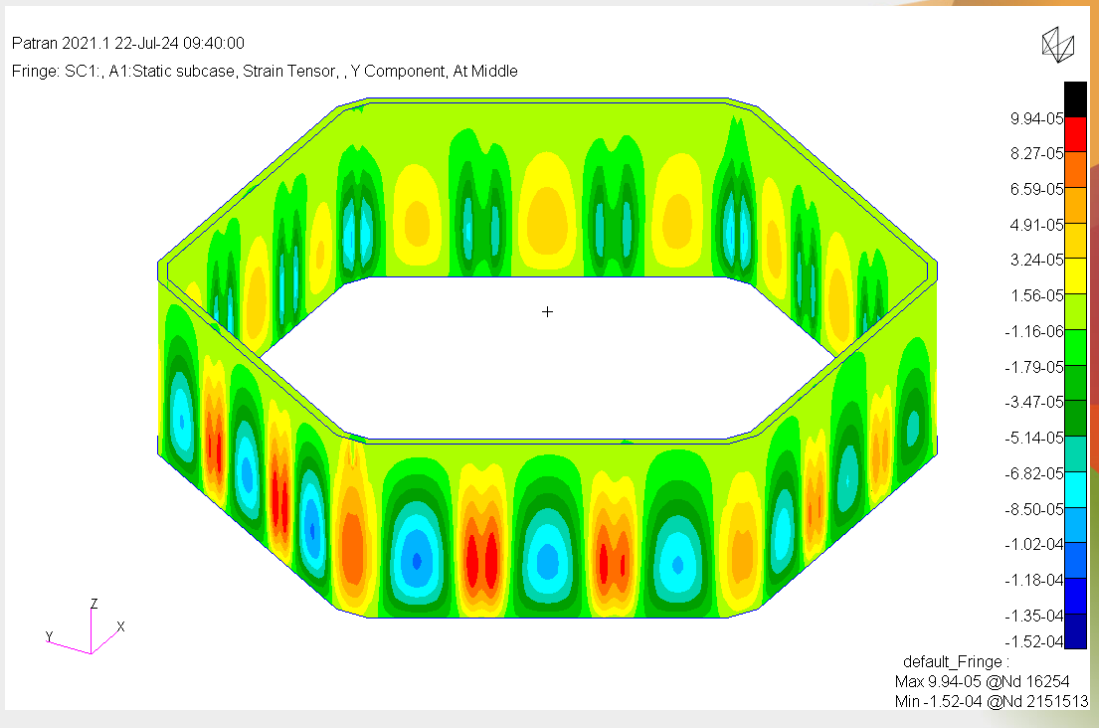
RESULTS

Strain distribution on outer perimeter walls

- Walls subjected to bending moment due to hydro loads
- No major influence of mooring lines loads



Vertical strain, outer perimeter wall. DLC6.1 Max_HydroMy

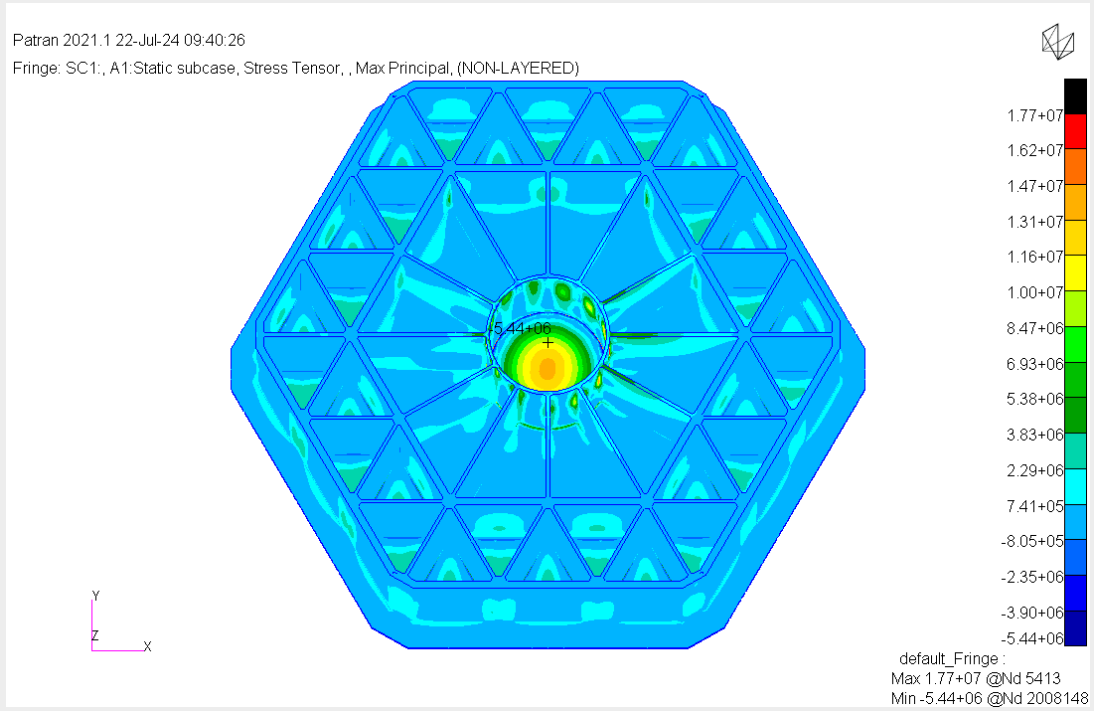


Horizontal strain, outer perimeter wall. DLC6.1 Max_HydroMy

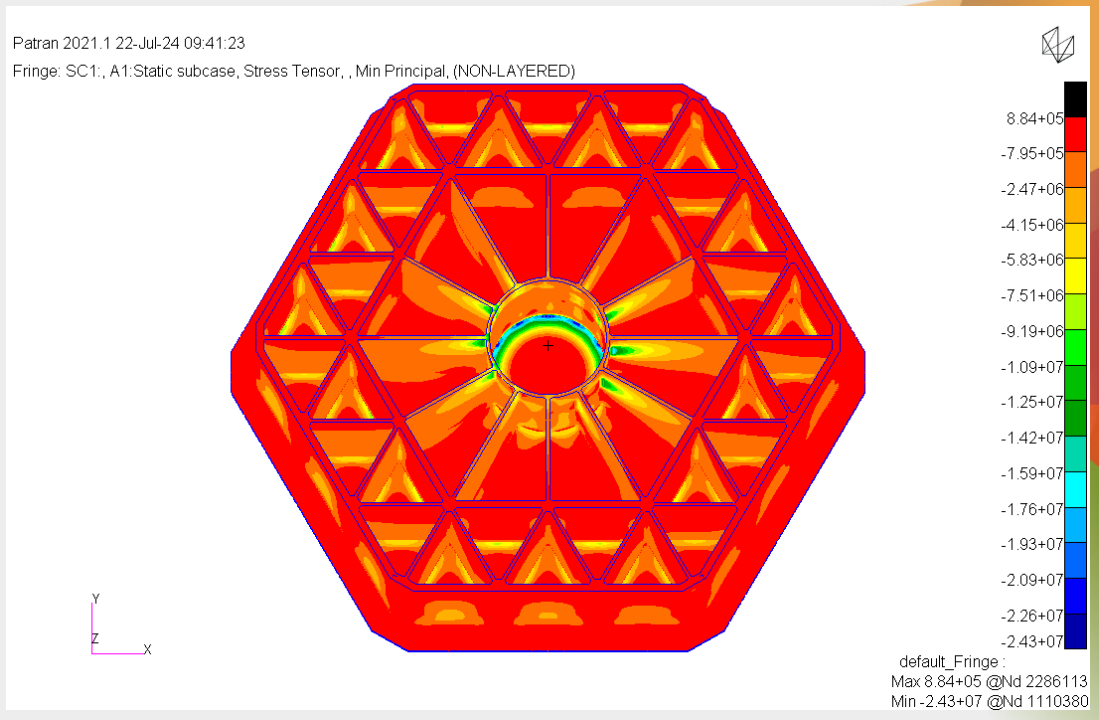
RESULTS

Stress distribution on concrete structure

- Hydro loads dominate overall behaviour
- Tower base and mooring loads local affection



Maximum principal stress [Pa], concrete. DLC6.1 Max_ HydroMy



Minimum principal stress [Pa], concrete. DLC6.1 Max_ HydroMy

CONCLUSIONS

Conclusions related to BERIDI's platform behaviour

- Perimeter walls and the heave plate are working in bending, with hydrostatic and hydrodynamic pressure loads dominating their behaviour
- The influence of the mooring lines and tower base forces is low compared with the hydrodynamic loads; and their effect is local.
- No moment reversal is observed. Depending on the movement of the platform, the bending law varies in magnitude but works in the same direction.

CONCLUSIONS

Conclusions related to the analysis methodology :

- The methodology and tools develop by CENER for loads calculation allow to obtain distributed loads on the platform in time domain
- With the methodology approach followed it is possible to perform detailed analysis of structures
- Up today, it has been used for ultimate state verification, but could be extended to fatigue analyses

Contact for further comments and questions:

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THANKS A LOT.

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