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# **Sloshing Analysis of a FPSO Cargo Tank**

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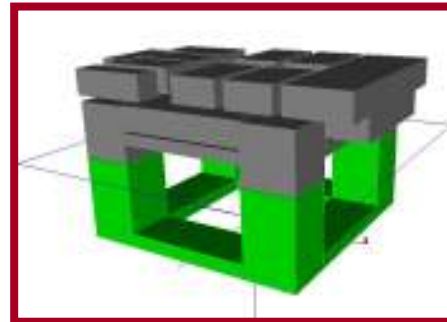


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## CENPES / EB-EP/ EG

### Main Attributions:

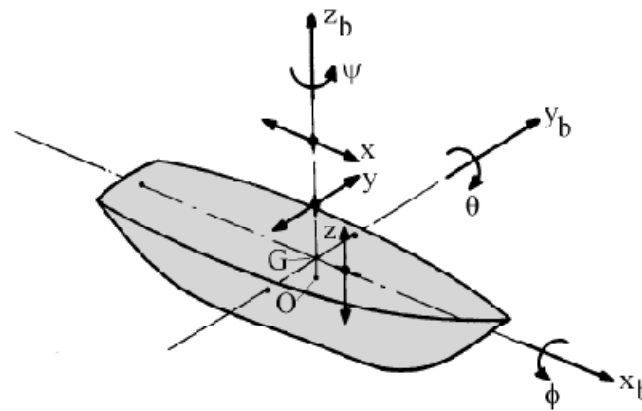
Structural Calculation for Basic Engineering Design of FPU's and Fixed Offshore units





## Problem Description

Floating units have six degrees of freedom:



Source: Offshore Hydromechanics



## Problem Description

- Roll motion is the most critical for FPSO's process plants;
- Roll motion is critical for crew's comfort;





## Why Roll Motion is so critical?

- Let's take a look on the roll motion equation and try to understand ...

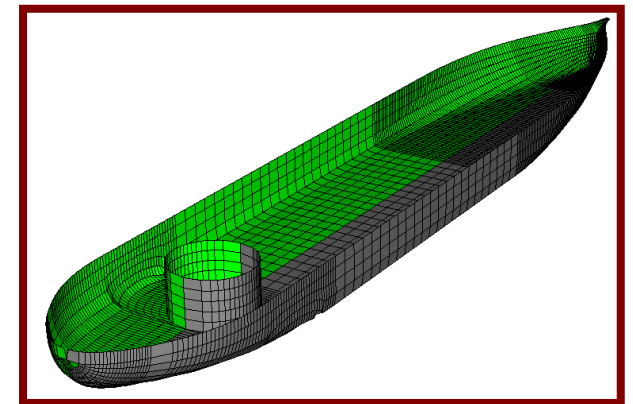
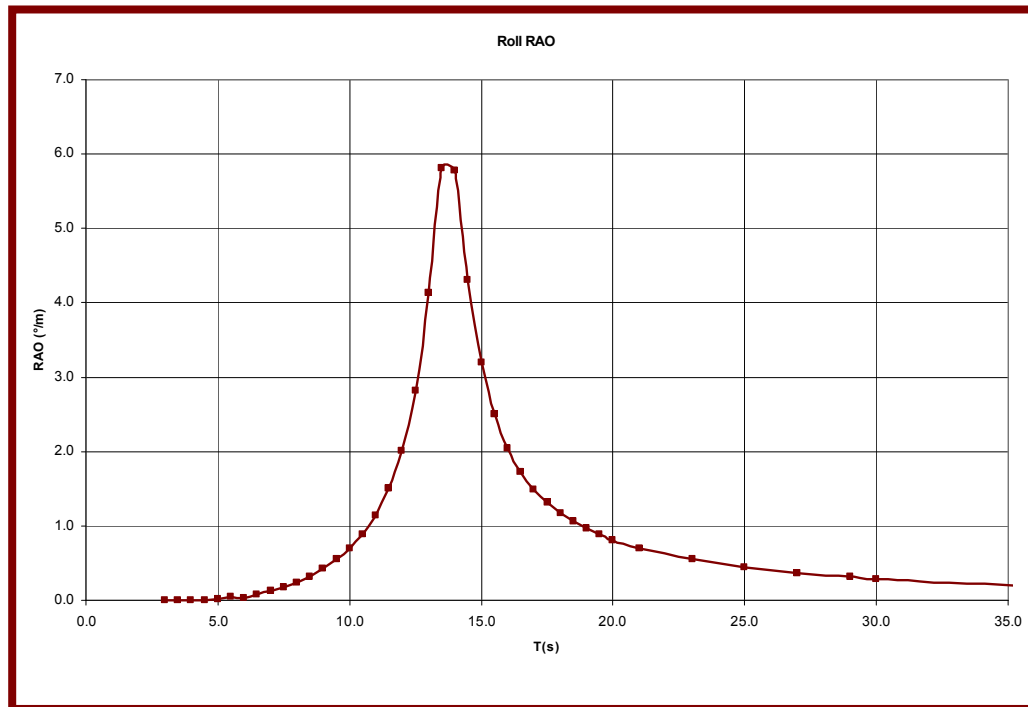
$$(I_{XX} + A_{44})\eta_4'' + B_{44}\eta_4' + (\Delta \cdot GM)\eta_4 = M_{wave}$$

The first equation term is related to motion acceleration and the third term is related to motion stiffness. The second term is related to damping and this is critical in the roll motion, since this motion does not generate waves and all damping is related to viscous part, which is a low component.



## Roll Response Amplitude Operator

A typical Roll Response Amplitude Operator is presented hereafter, this RAO is obtained using a Potential Theory software



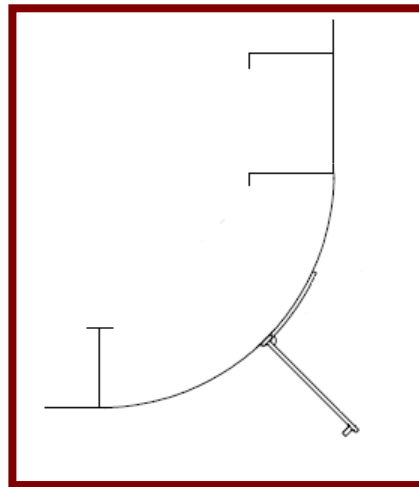


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## Useful Methods to Mitigate Roll Motion

### How Can We Mitigate Roll Motion?

-Increasing viscous damping, building bigger bilge keel. This is a very useful resource but many times it is not enough to mitigate roll motion.



- Using a cargo tank as a vibration passive absorber. This solution maximizes the sloshing inside the cargo tanks.



## Cargo Tank as Passive Vibration Absorber

-In order to mitigate roll motion to acceptable levels of process plant operation and crew's comfort, a cargo tank can be used as a passive vibration absorber;

- The tank filling shall be calibrated to have its resonance frequency coincident with the roll motion natural frequency. It can be obtained using the following relation:

$$T_{n-TANK} = \frac{2 \cdot b_{TANK}}{\sqrt{g \cdot h}}$$



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## Passive Vibration Absorber

### Cargo Tank as Passive Vibration Absorber



No stabilizer tank

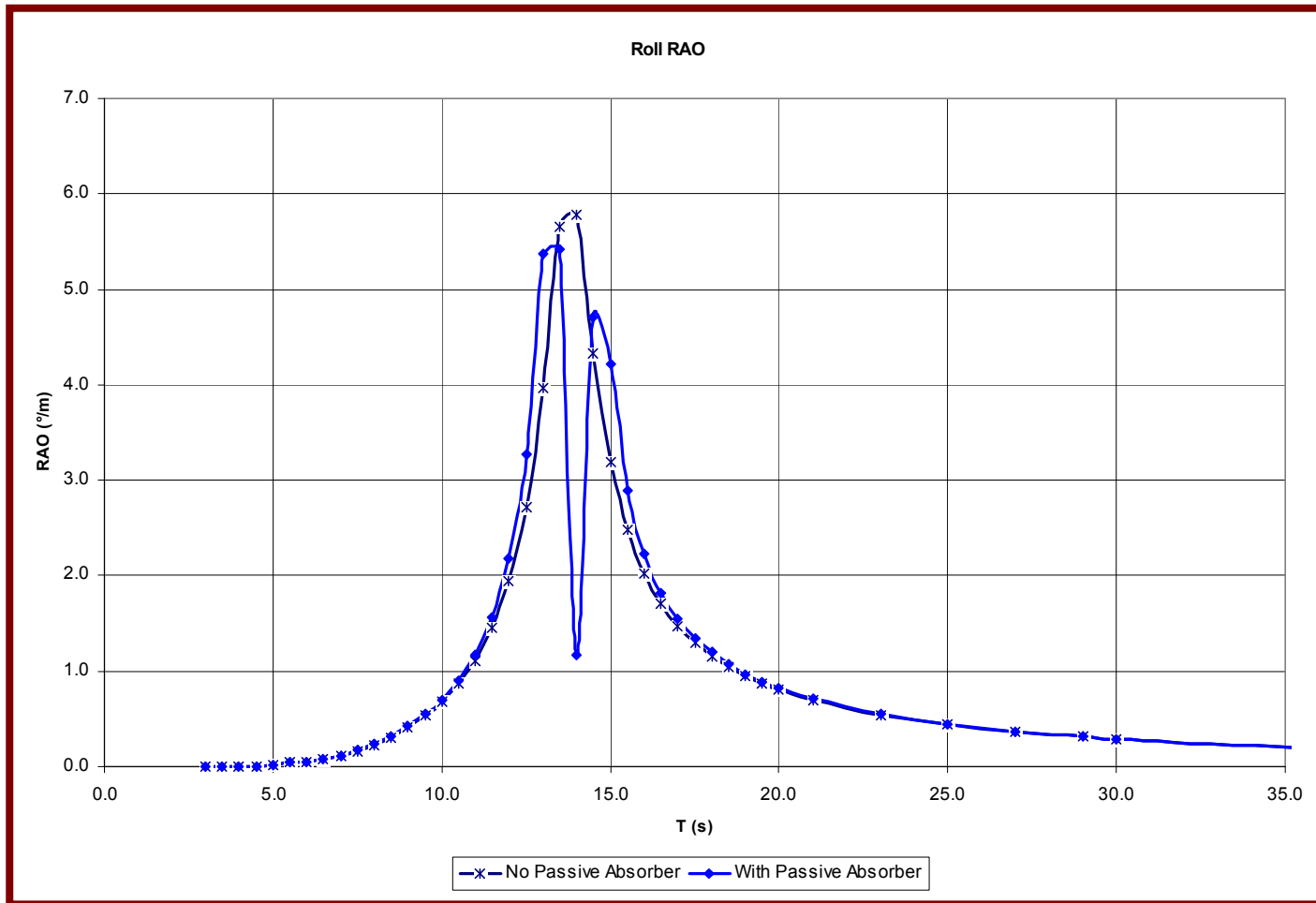


With stabilizer tank

Source: M.Sc. of Arthur Curty Saad



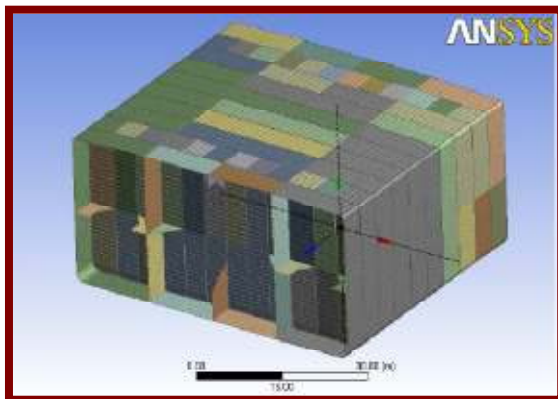
# Roll RAO with Passive Vibration Absorber



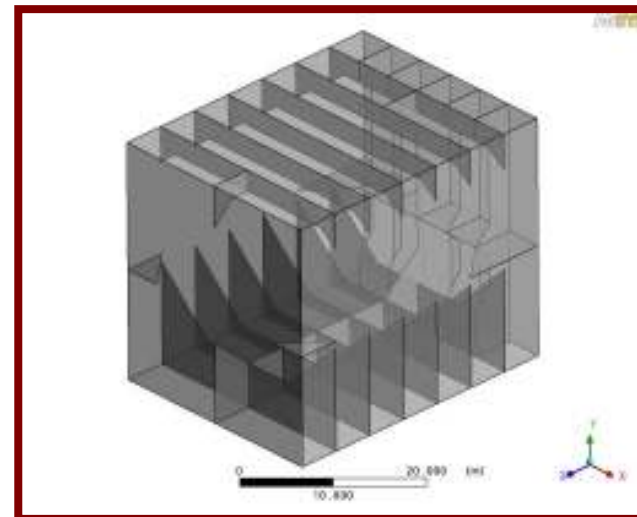


## Loads Inside the Structure

- In order to evaluate the induced loads inside the cargo tank the best choice was perform a CFD analysis, since it is much cheaper and faster than building a scale model;
- CFD analysis provide means of estimate the pressure along any point on the tank structure while a model test would allow measure only on some points.



Hull Geometry

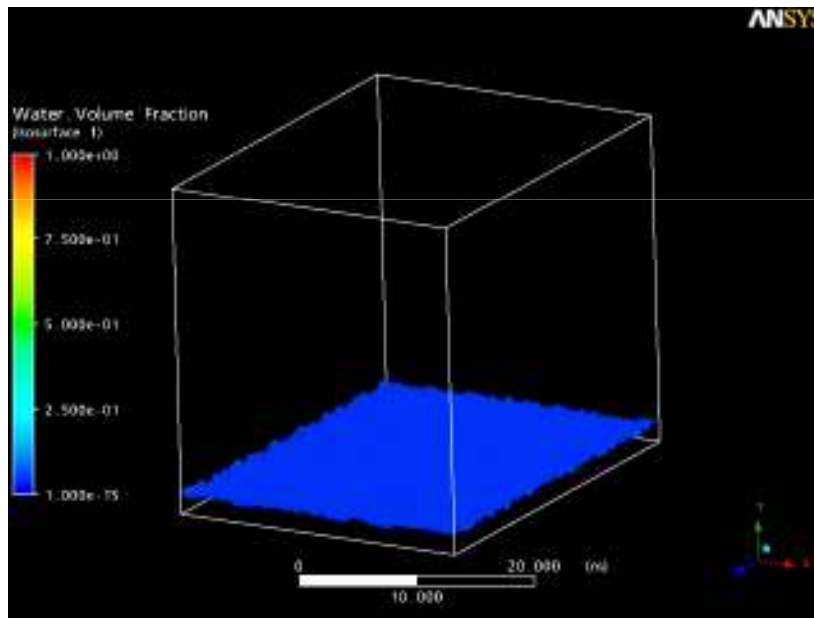


Center Tank Geometry

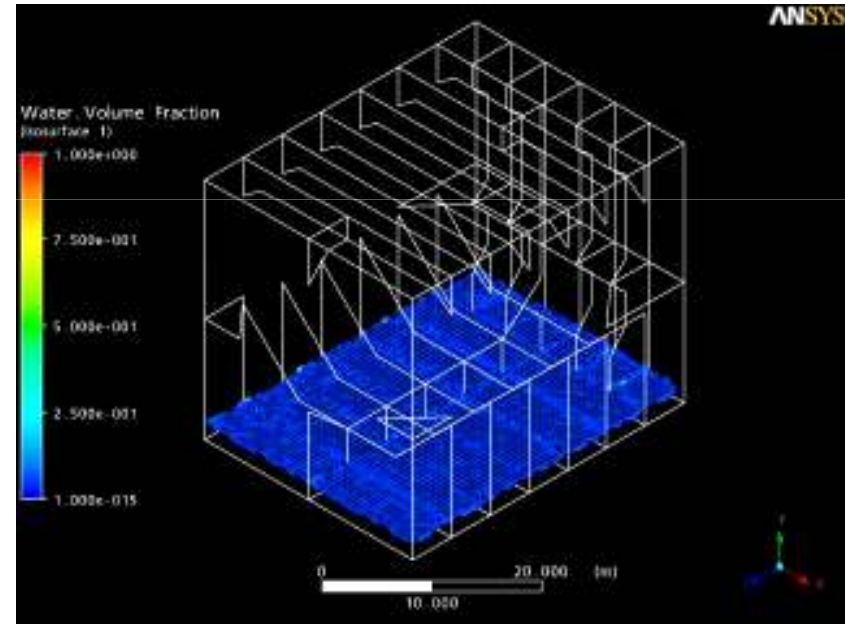


## Fluid Behavior inside the Tank

- Stabilization tank synchronized with roll natural frequency



Stabilizer tank with no internal reinforcements

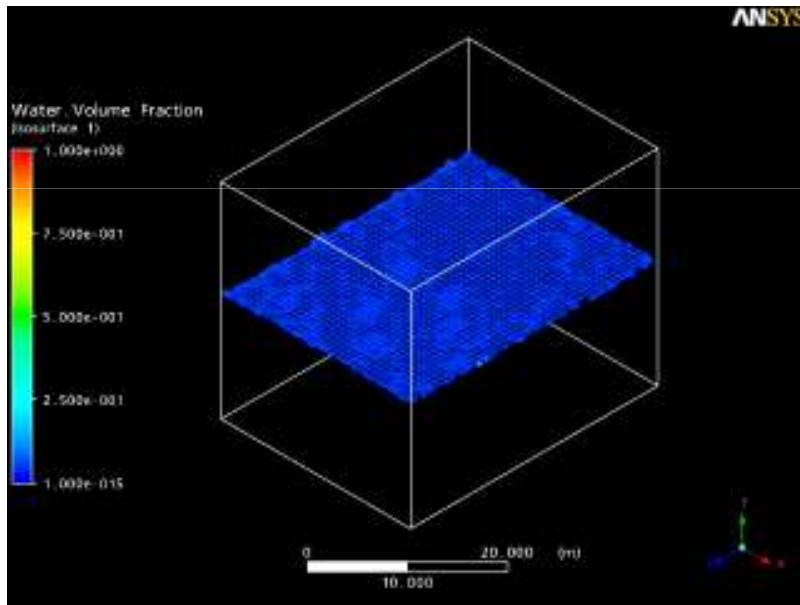


Stabilizer tank with internal reinforcements

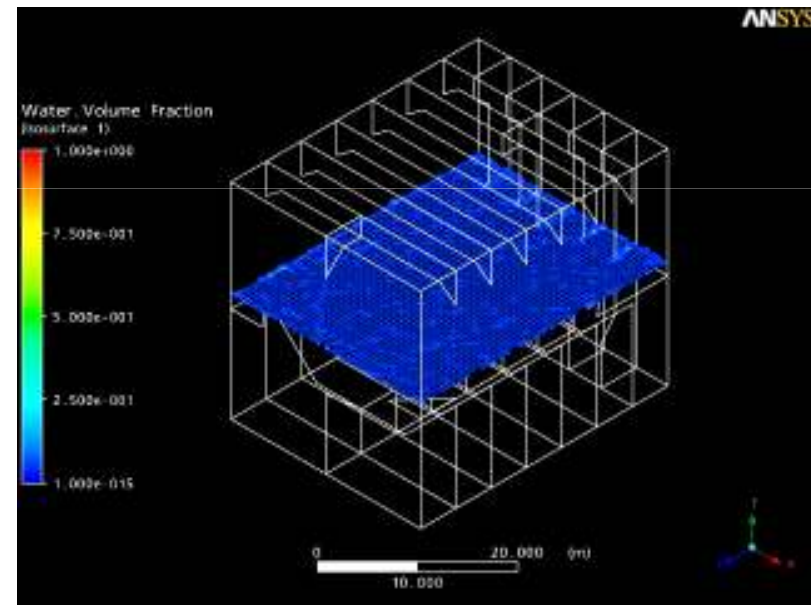


## Fluid Behavior inside the Tank

- Stabilization tank with 50% of maximum level



Stabilizer tank with no internal reinforcements

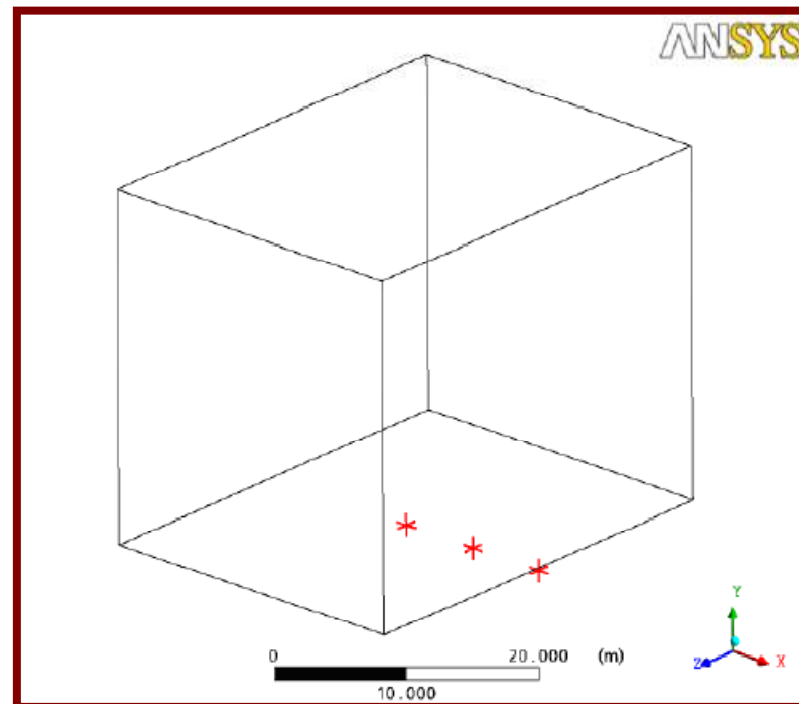


Stabilizer tank with internal reinforcements



## Pressure Monitoring

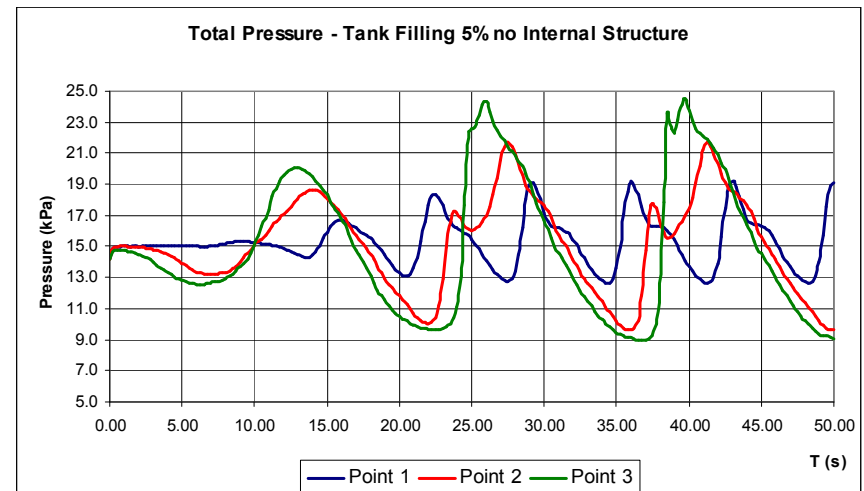
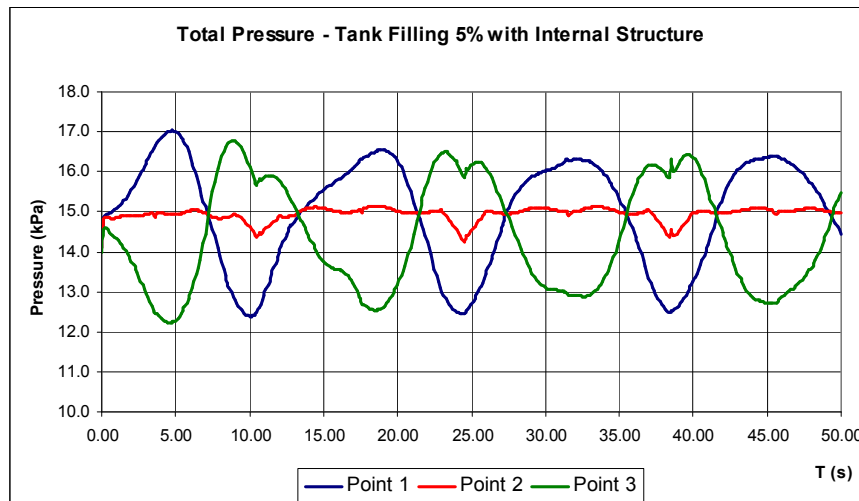
- The Pressures inside the tank was monitored on the points presented hereafter.





## Pressure Monitoring

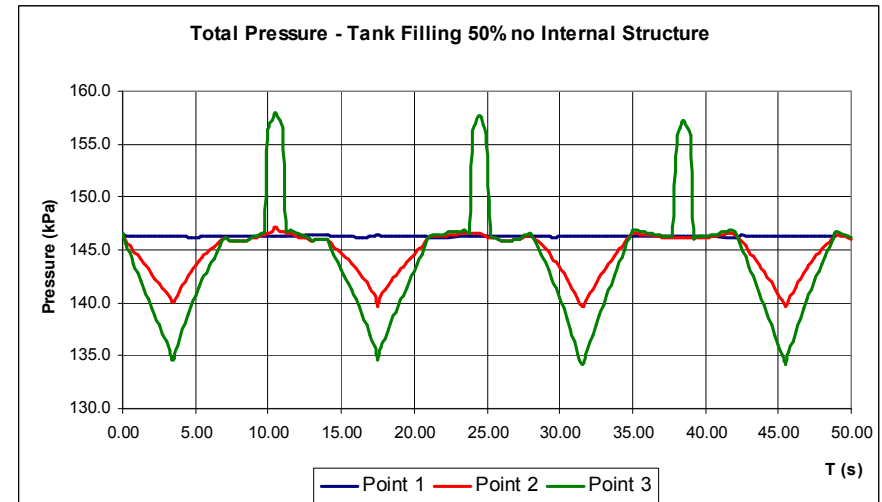
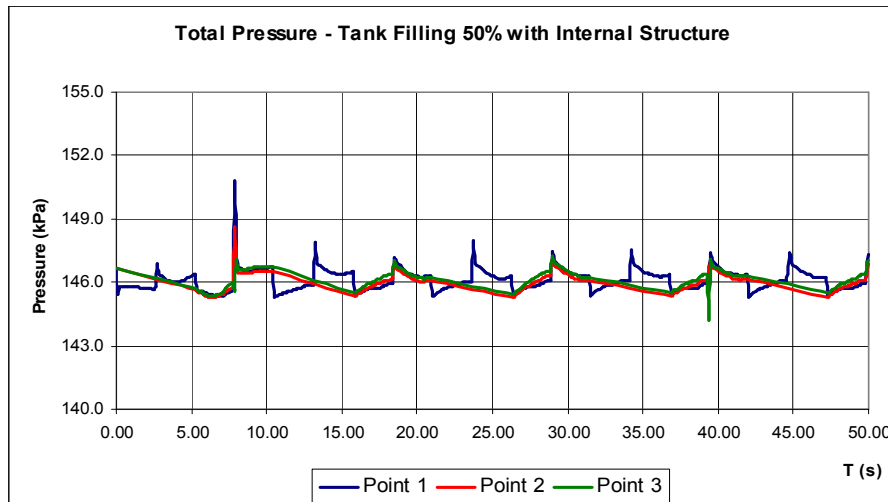
- The graphics below presents the total pressure at the specified measurement points for the tank filling at 5% of the maximum.





## Pressure Monitoring

- The graphics below presents the total pressure at the specified measurement points for the tank filling at 50% of the maximum.





## Conclusions

- The CFD simulation showed how the structures inside the stabilizer tank influence affect its natural frequency;
- The hydrodynamic pressure due to liquid motion are directly influenced by the internal structure;
- The results achieved with CFX permit to perform a more accurate structural analysis instead of using loads calculated by international codes.



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**THANK YOU !!!**