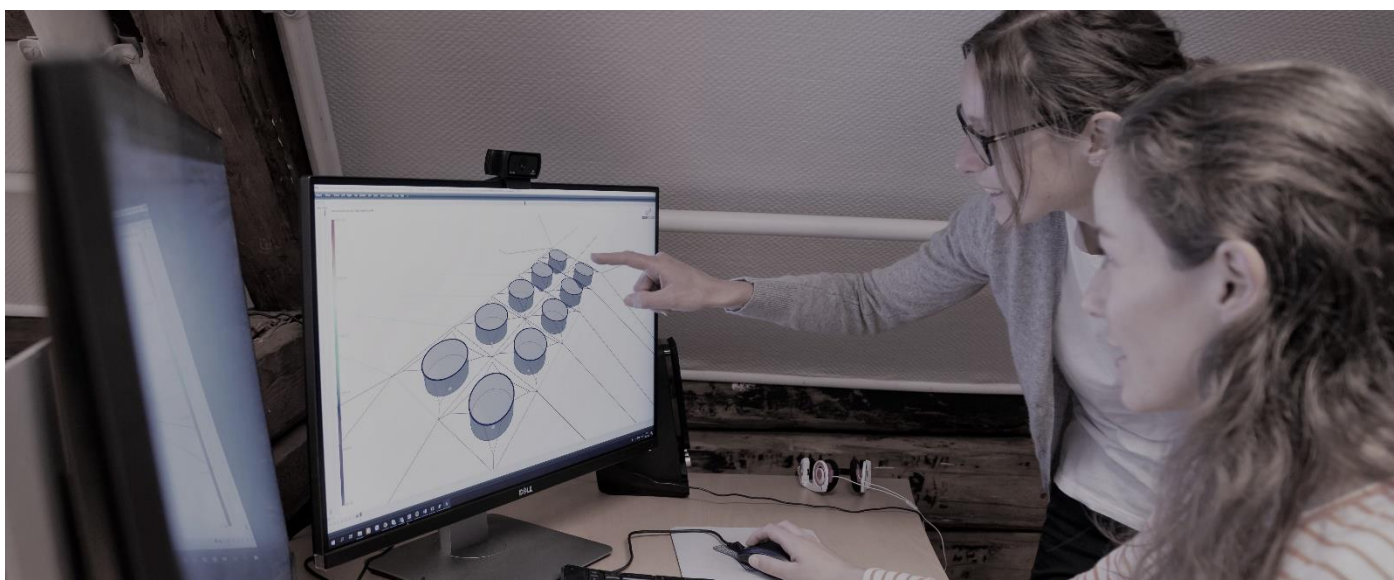


AquaSim training courses

- Tarpaulin closed compartment, inner fluid mass



Revision: 1.0

AquaSim version: 2.22.0

Aquastructures AS
Kjøpmannsgata 21, 7013 Trondheim
Norway

Content

1	Prerequisites.....	3
2	Introduction.....	3
3	Fluid parameters internally in tank	4
3.1	Scaling factor, fluid mass horizontal	5
3.2	Scaling factor, fluid mass vertical.....	5
3.3	Horizontal radius inner fluid mass.....	6
3.4	Oblique elements	7
3.5	Inside and outside definition of compartment	8
4	Analysis.....	8
5	Conclusive remarks.....	12
6	References.....	13
7	Revision comments.....	13

1 Prerequisites

The tutorial presents a simple case study with the purpose of demonstrating functionality in AquaSim.

It is assumed that the user is familiar with the basic principles of modelling and specifying material parameters in AquaEdit, as well as conducting analyses. If you are looking for an introduction to AquaSim we advise you to start with the Basic program tutorials.

2 Introduction

In this tutorial, you will be introduced to how the inner fluid of a hemispherical shaped tarpaulin attached to a floater is handled dynamically. This includes the following steps:

- Refer to tutorial for static analysis for modelling.
- Explanation of parameters relevant for dynamic response.
- Analysis to validate the dynamic effect of inner water mass.

Closed compartments with internal fluid are common in aquaculture and marine structures, and their dynamic behavior can have a significant impact on overall system response.

This tutorial builds on the model introduced in (Aquastructures AS, 2025b) (shown in Figure 1) and demonstrates how AquaSim handles the inner water of a hemispherical tarpaulin attached to a floater statically. The focus is on defining the inner water parameters, applying them within AquaEdit, and validating the resulting behavior through AquaView.

The case study provides a step-by-step example of how internal fluid mass can be modeled and checked. While the tutorial emphasizes correct parameterization and validation, it does not address more complex internal fluid dynamics such as sloshing or free-surface oscillations. These effects can be approximated manually in AquaSim, but they are outside the scope of this training exercise.

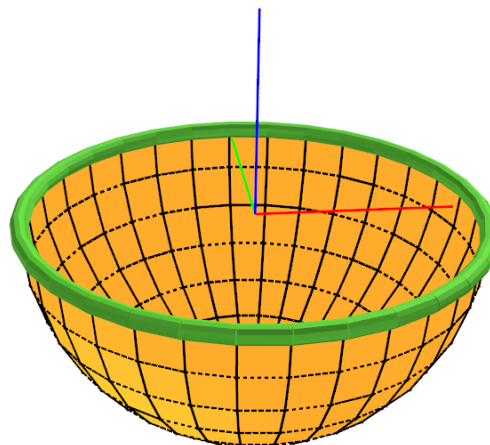


Figure 1 Hemispherical tarpaulin and floater, in AquaEdit

3 Fluid parameters internally in tank

Focus will be on the parameters found in the “Fluid parameters internally in tank” section under Impermeable properties in AquaEdit, see Figure 2.

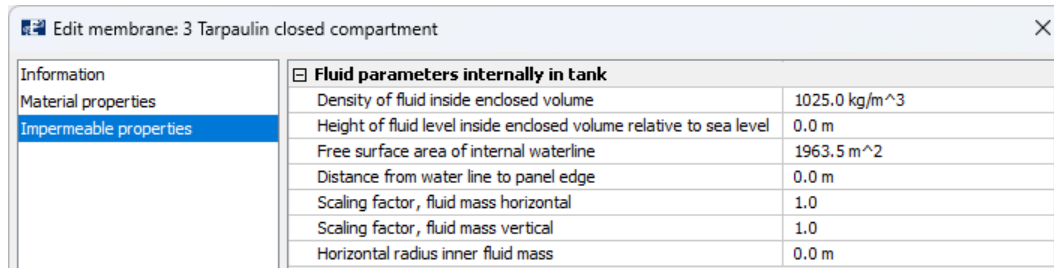


Figure 2 “Fluid parameters internally in tank”, AquaEdit

The first four parameters consider weight and static equilibrium of the water inside the compartment:

- **Density of fluid inside enclosed volume:** this is the density of the fluid inside the compartment. Normally 1025 kg/m³ for seawater and 1000kg/m³ for fresh water.
- **Height of fluid level inside enclosed volume relative to sea level:** this is the height of the water (positive upwards) of water inside the compartment. This is the waterline in the drawn non-deformed structure. This determines the volume of the fluid inside the compartment. This volume is assumed constant through the analysis, such that if the structure deforms downwards (i.e. the volume below the waterline becomes larger) the height of this fluid level decreases, and vice versa.
- **Free surface area of internal waterline:** this is the area of the water surface inside the compartment. This area is assumed constant through the analysis. So, when the compartment deforms this is the area which the fluid is “pushed through”.
- **Distance from water line to panel edge:** this parameter is set in situations where you want the water to pour out of the compartment. The water will pour out if this value is exceeded (this is relative to the lowest point of the upper edge across the compartment). Note that there is no mechanism working the other way, meaning that the total water volume in the compartment can only decrease as analysis progress.

The next parameters regulate how the fluid should behave inside the compartment, in other words how the inner water mass should respond dynamically.

- **Scaling factor, fluid mass horizontal:** portion of the fluid inside that should move horizontally with the compartment.
- **Scaling factor, fluid mass vertical:** portion of the fluid inside that should move vertically with the compartment.
- **Horizontal radius inner fluid mass:** regulates the portion of fluid inside that should move horizontally with the compartment. It also regulates how much fluid on the outside that should move outside (added mass).

These three parameters are considered in this tutorial.

3.1 Scaling factor, fluid mass horizontal

This parameter determines how much of the fluid inside the compartment that should move horizontally with the compartment. AquaSim keep track of the element's position and finds the distance to compartment's geometric centreline (see Figure 3), this is called the "horizontal radius inner fluid mass". This distance forms the basis for how much fluid mass is applied to the element in horizontal direction. The parameter "Scaling factor, fluid mass horizontal" scales this radius. Meaning, if this factor is 0.0 no fluid mass is added to the element, and if 1.0 the full radius is applied for adding fluid mass to the element.

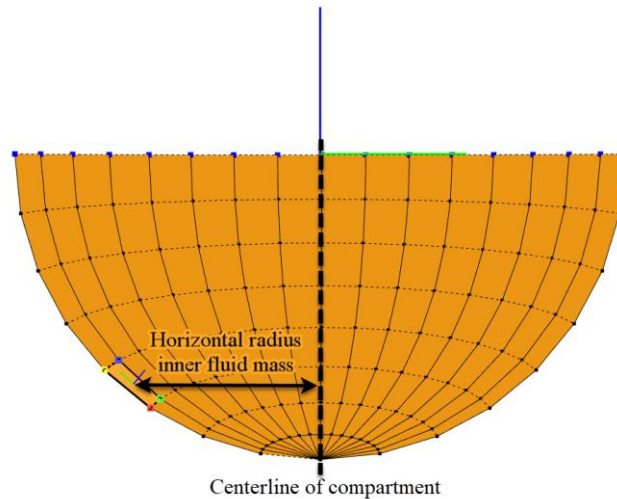


Figure 3 Horizontal distance from an element to the compartment's centerline

3.2 Scaling factor, fluid mass vertical

This parameter determines how much of the fluid inside the compartment that should move vertically with the compartment. AquaSim keep track of the element's position and finds the vertical distance to the water line inside the compartment (see Figure 4). This distance forms the basis for how much fluid mass is applied to the element in vertical direction. The parameter "Scaling factor, fluid mass vertical" is a factor that scales this distance. Meaning, if this factor is 0.0 no fluid mass is added to the element, and if 1.0 the full distance is applied for adding fluid mass to the element.

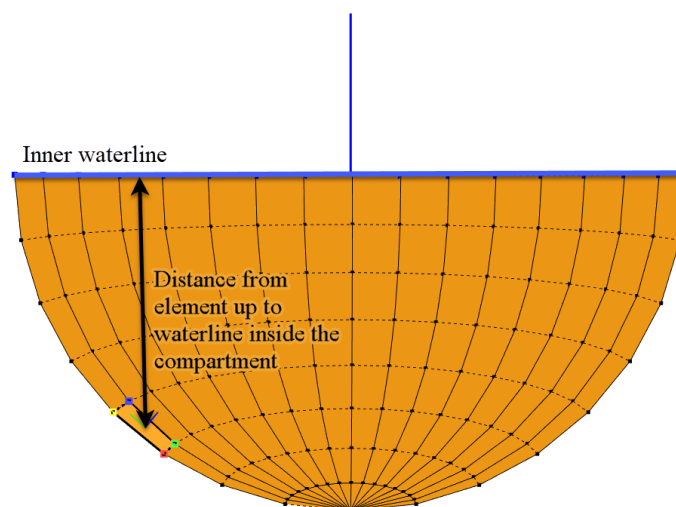


Figure 4 Distance from an element to the water line inside the compartment

3.3 Horizontal radius inner fluid mass

This is the horizontal distance from each element to the geometric centreline of the compartment. It is applied to calculate added mass on the outside of the compartment. It works as follows:

- If this set to 0.0: it means that AquaSim calculates where the centreline is and then find the horizontal distance (or radius) from each element to the centreline. This is then applied to calculate added mass on the outside of the compartment for each element. See the leftmost illustration in Figure 5. Note that the distance to the centre of the compartment horizontally is multiplied with the normal vector of the element such that for a square box, the radius is the cross section distance.
- If this is a positive value: then this value is applied as the horizontal inner radius for all elements, irrespectively as to where the elements are located with respect to the centreline. See the rightmost illustration in Figure 5.

Note that this parameter also contributes to determine the added mass for fluid on the outside of the compartment.

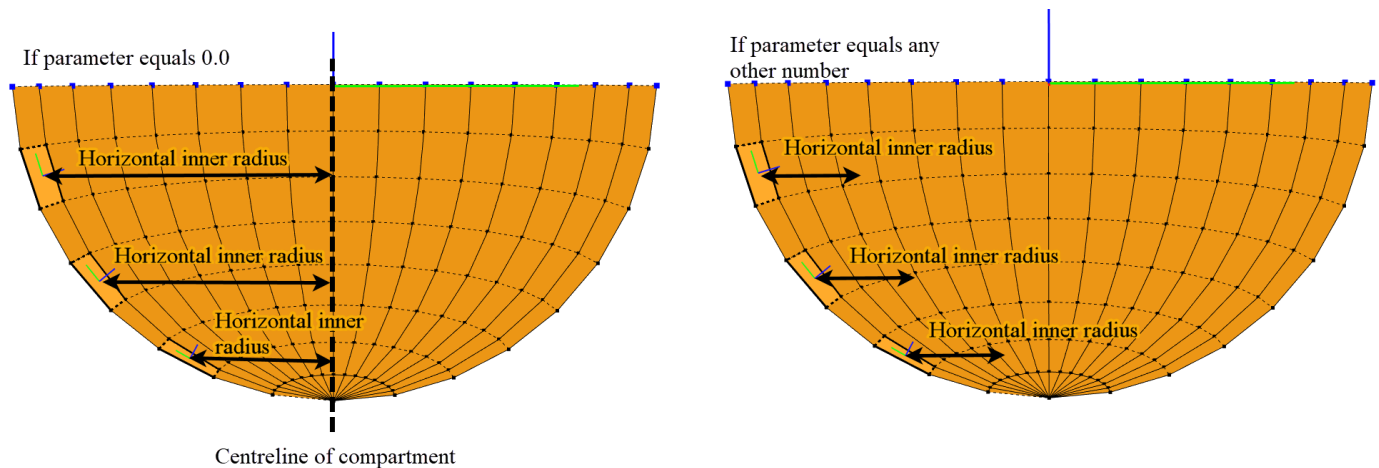


Figure 5 Horizontal radius of inner water fluid

3.4 Oblique elements

The mass of fluid inside the compartment is placed on elements only in normal direction to the element. For oblique elements mass of water inside (and other added mass) is applied normal to the element, as shown in Figure 6.

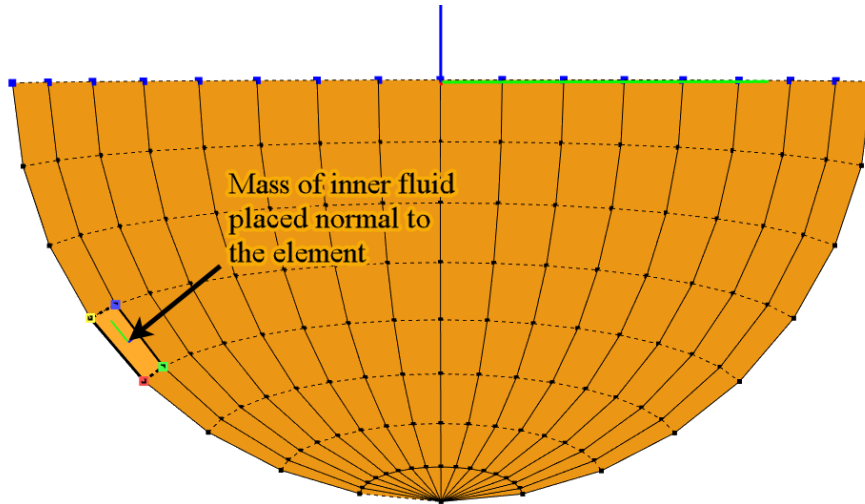


Figure 6 Mass of inner fluid on element

For oblique elements, a combined factor based on considering both the vertical factor and the horizontal factor is applied, see Figure 7 for example of an oblique element.

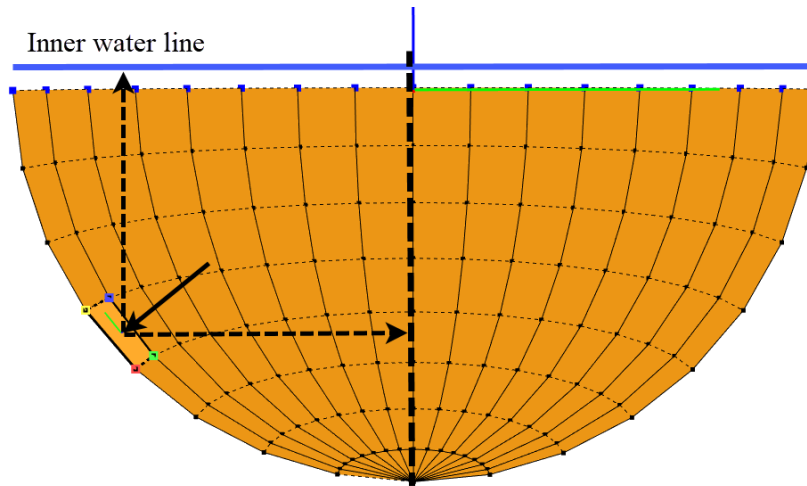


Figure 7 Mass of inner fluid for oblique elements

The factor is based on how much the element faces vertically vs horizontally. With reference to Figure 7 we define an orthogonal vector $\vec{n} = (n_x, n_y, n_z)$, the added mass to be applied to an oblique element is then:

$$Am_{use} = abs(n_z)Aim_{vert} + \sqrt{(1 - n_z^2)}abs(n_{hor})Aim_{hor}$$

where

- Aim_{vert} is the mass of inner fluid if the element were located in the horizontal plane.
- Aim_{hor} is the mass of inner fluid if the element were located on the vertical plane.

3.5 Inside and outside definition of compartment

When working with closed compartments, it is important to keep track of what is considered inside and outside such that the parameters achieve correct references. The membrane normal (blue line) should always point into the volume. In AquaEdit, the view-option “Membrane sides” is a useful tool to keep track of this.

4 Analysis

In this analysis we are going to find the eigen period of the hemisphere through analysis and compare this with analytical calculations.

Consider the hemisphere similar to the one from (Aquastructures AS, 2025b). Some changes are done in the model. First, a grid of beam elements is added on top of the membrane panels. The purpose of adding this is to make the model more rigid such that the membrane panels do not deform, see Figure 8. Volume, weight and drag parameters are remove so that the beams only contribute to stiffness in the model. All nodes are only allowed to displace along x-direction. Because of this, the floater becomes redundant and can be deleted.

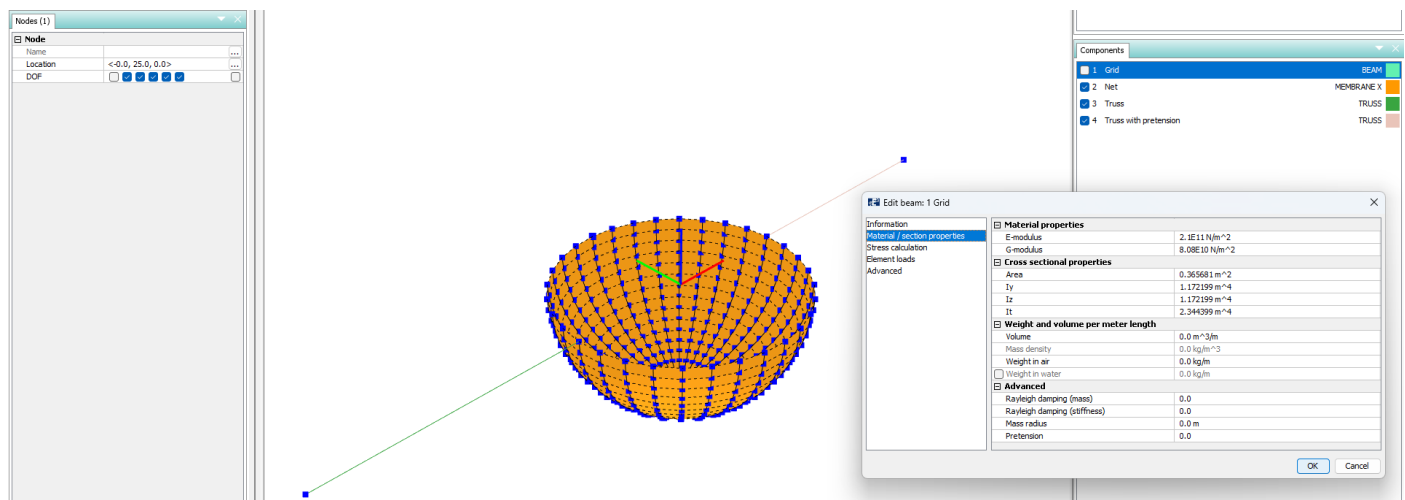


Figure 8 Beam added on top of the membrane

Parameters for the membrane panels are presented in Figure 9.

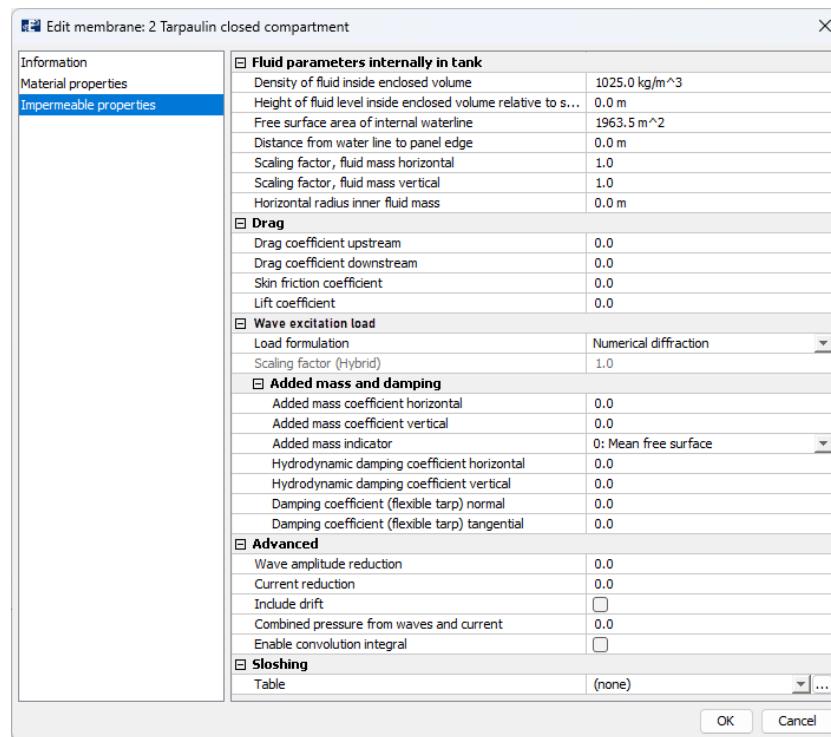


Figure 9 Membrane panel parameters

Then trusses are added on each side of the hemisphere, one of are assigned pretension and Linebreak in the first dynamic step.

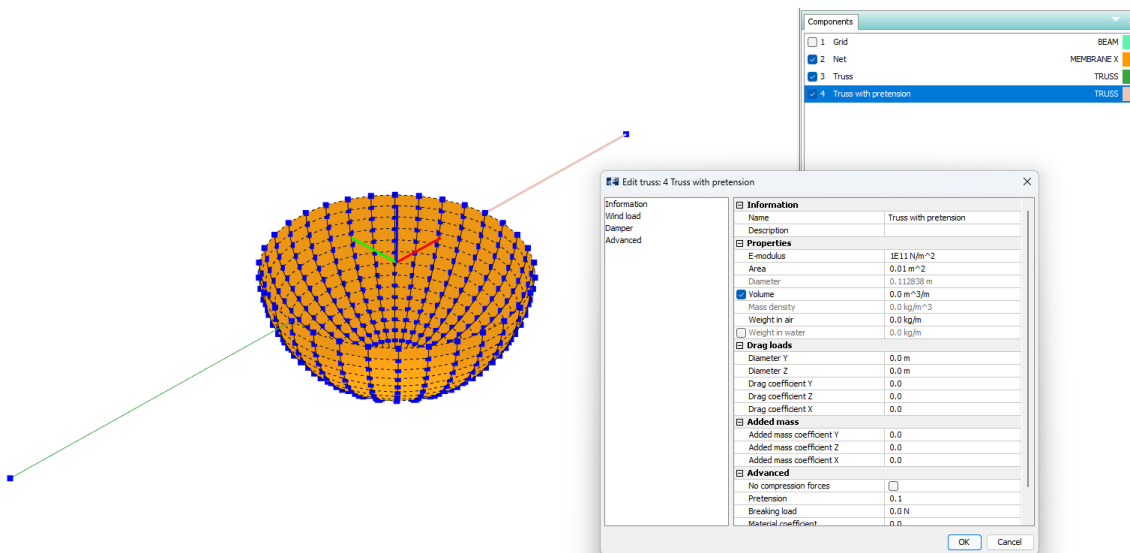


Figure 10

Calculating the mass of inner fluid analytically for the hemisphere, and the eigenperiod for the system, the values as presented in Table 1 are obtained.

Table 1 Data for hemisphere, truss and eigenperiod

Data closed section	
Radius [m]	25.0
Surface area [m ²]	1963.5
Height of fluid level inside enclosed volume relative to sea level [m]	2.0
Volume Hemisphere [m ³]	32724.9
Volume 2 meter above [m ³]	0.0
Total volume [m ³]	32724.9
Total mass [kg]	33543046.56
Data truss	
Cross sectional area [m ²]	0.01
Elastic module [Pa]	1.00E+11
Length [m]	50
K	2.00E+07
Data eigenperiod	
Eigenfrequency ω_e [2 π /s]	0.77
Eigenperiod T_e [s]	8.14

Total mass of inner fluid for the model can be found in the #hydro.txt-file, as seen in Figure 11.

_01hydro.txt	02.10.2025 13:52	Tekstdokument	13 kB
--------------	------------------	---------------	-------

Figure 11 #hydro.txt-file generated during analysis

When loading the #hydro.txt-file, one may see that the mass of fluid inside the compartment corresponds approximately with the analytical. This is seen by comparing numbers in Figure 12 and “Total mass [kg]” in Table 1.

Values in global coordinate system

STEP 4

Inner water mass [Tonne]

		X,	Y,	Z,
Component	2	0.33282695E+05	0.33283598E+05	0.33100399E+05

Figure 12 Weight of mass inside the compartment

Analysis with a wave period of 10s (amplitude =0) is run. The displacement in x-direction of the hemisphere is presented in Figure 13. The eigenperiod of this system is the time difference between two displacement maxima. The first max is found at $t=0$, and the second is found at approximate $t=8.10$ s. A period of 8.15 seconds correspond well with the analytical value found in Table 1.

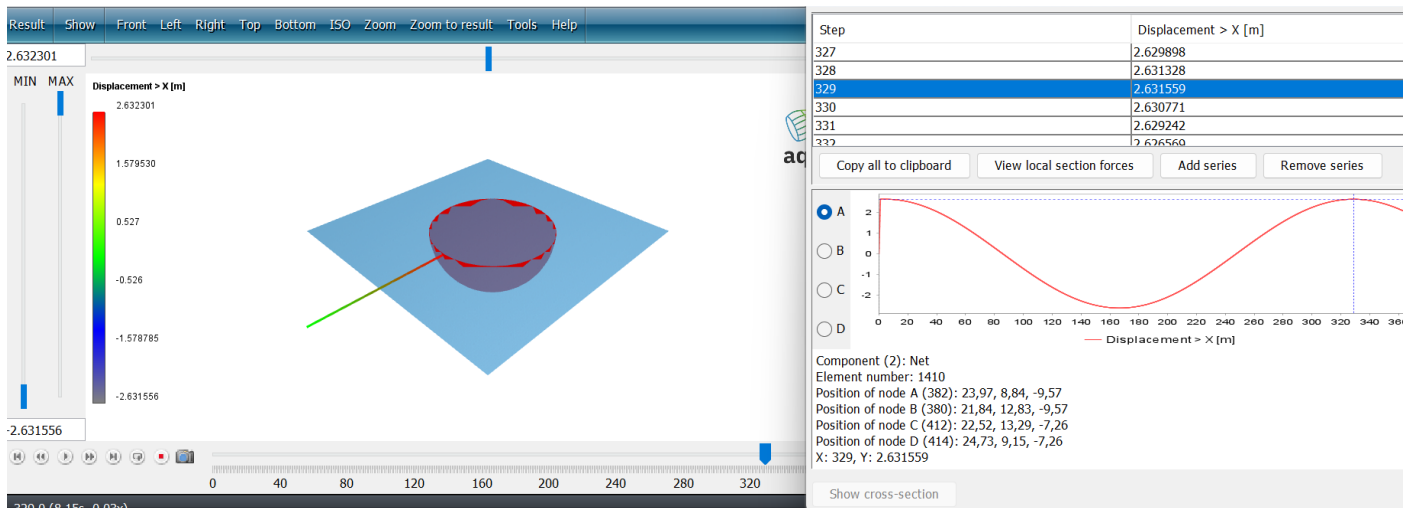


Figure 13 Horizontal displacement of hemisphere

5 Conclusive remarks

This tutorial has demonstrated how AquaSim can be used to model and analyse a closed compartment with internal water mass. Through a step-by-step case study, we have shown how to define the relevant parameter for fluid inside the compartment, establish the analysis model in AquaEdit, and validate the dynamic response in AquaView.

By comparing numerical results with analytical estimates, the exercise confirmed that the implemented inner fluid mass model reproduces the expected behaviour of the system. This provides confidence in the modelling approach and can be useful to validate that fluid parameters are as expected when working with closed compartments. Users are encouraged to carefully self-validate input for all parameters, not only those mentioned here.

It should be noted that this tutorial does not address internal fluid dynamic effects, such as free-surface motion, sloshing, or pressure oscillations, within the closed compartment. Simplified representations of sloshing can be introduced manually in AquaSim. However, these are outside the scope of the present tutorial. Such effects may be relevant in scenarios involving partially filled compartments, transient loading, or strong dynamic excitation.

6 References

Aquastructures AS. (2025b). #2091 *Tutorial closed compartment current*.

7 Revision comments

Revision no.	Comment
1.0	First publication

--- End of document ---