Solico Projects B.V.
Innovatiepark 24
NL-4906 AA Oosterhout
The Netherlands
Tel.: +31-162-462280
E-mail: projects@solico.nl
Bankrelatie: Rabobank Oosterhout
Rek.nr. NL36 RABO 0302 6988 68
K.v.K. Breda nr. 62808575

User Manual

Last updated: February 20th, 2024

Please read this user manual carefully if any questions arise, please contact the amphora Admin.

Amphora@solico.nl

Table of Content

1. General information

Welcome to the Amphora User Manual.

Amphora is a user-friendly web-based software designed for creating GRP tanks and silos that meet EN13121 standards. The software caters to a broad audience, offering value to engineers, sales representatives, tank and silo buyers, as well as manufacturers.

Amphora key advantages:

- Material database
  - ➢ reduces errors
- Project database
  - ➢ access all your projects
- On-screen report
  - ➢ overview of design performance
- Downloadable report
  - ➢ governing bodies
- Wide variety of geometric configurations
- Built-in wind and snow load
- Always up to date (EN13121-3)
- Solico can step in
- Adaptable, suiting client requirements
- 1 database within your company, accessible by multiple users
- Structural design of tank/silo within 10 min
- Quotation phase
  - ➢ Reduces risk of higher-than-expected material cost
  - ➢ Optimize-function optimises laminate thicknesses
- Engineering reports

Amphora's current capabilities:

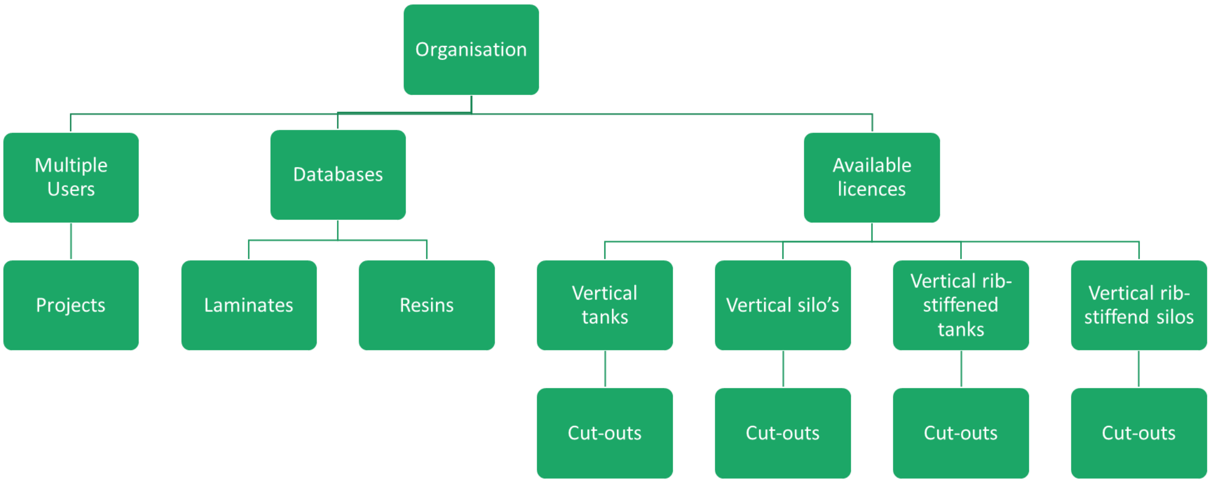
- Different modules available:
  - Vertical tanks
  - Silos
  - Rib stiffened vessels
  - Horizontal tank (under development)
- Standard features:
  - Cut-outs
  - English, Italian and German reporting

2. Optimal practices for maximizing Amphora efficiency

- Always click “update” in the lower left corner of each screen when you make a change to your project, otherwise your modification will not be saved
- Amphora is based on the EN13121 standard, so it is advised to have a copy of the EN13121-1, -2 and -3 available

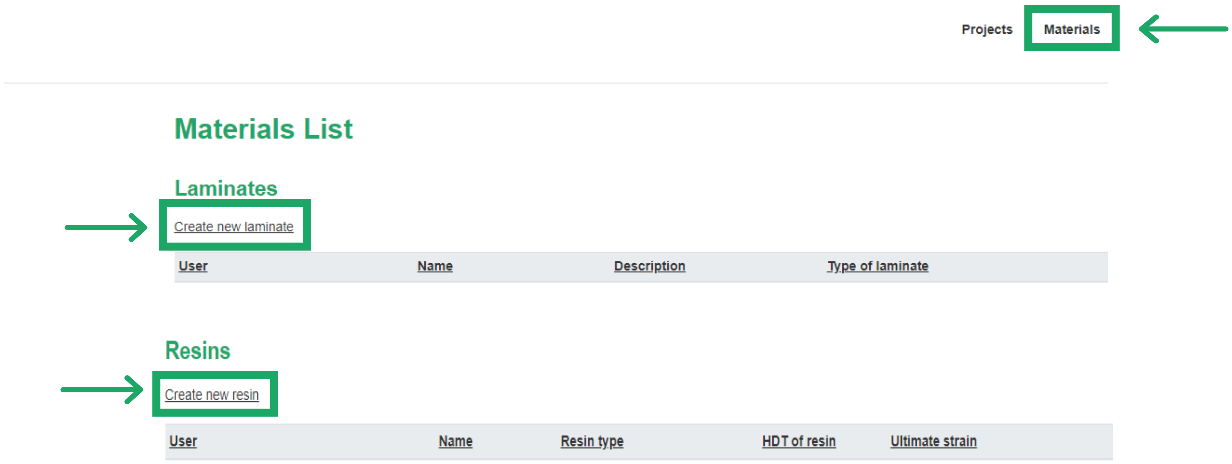
3. Program structure

It’s good to realise that within Amphora, all licensing and databases are organised on the “organisation” or company level. Each organisation can have multiple licenses for different project types. This organisation has a material database that can be accessed by all its users for any project. All of its users can generate and manage project for all active licenses.



4. Material database

This section focuses on the Materials Database. Each user possesses a private material database, enabling the storage of personalized laminates and resins. Access it by clicking on the "Materials" heading.

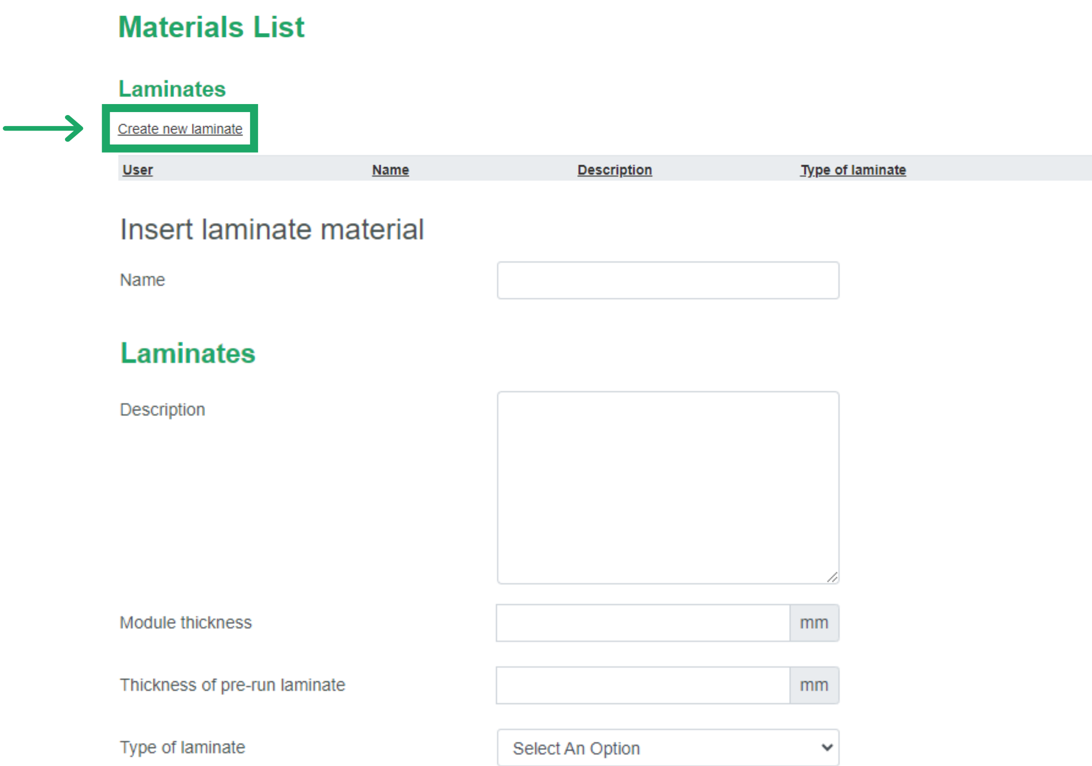


Within the Materials Database, users can input their specific laminates and resins. Amphora does not come with predefined standard laminates and resins. For new users, the list starts empty, allowing customization.

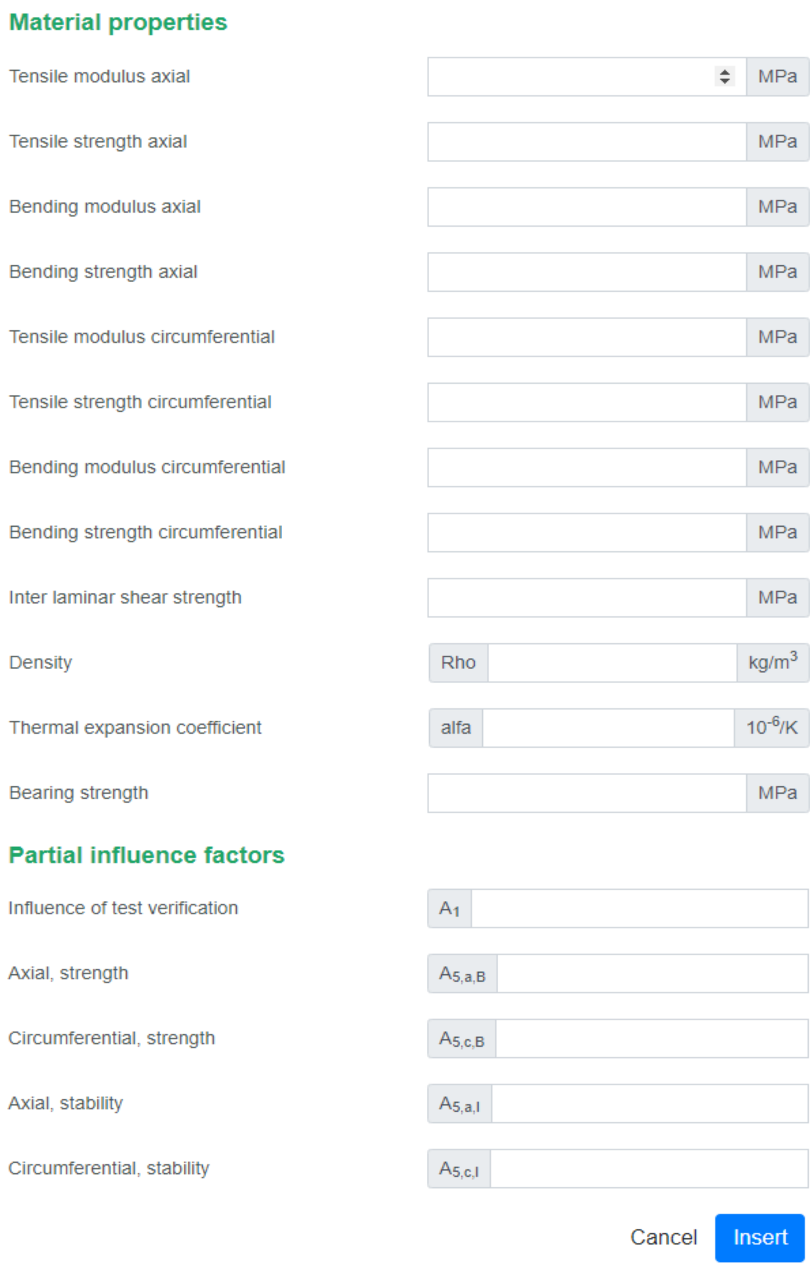
Before starting a project, insert a laminate and a resin into the Materials Database.

4.1. Adding a laminate

To add a laminate, go to the Materials tab, click "Create New Laminate," and give it a name. Include a description, such as a note or reference. Input thicknesses of each module and the pre-run laminate (if applicable), and select the laminate type (e.g., CSM laminate, mixed CSM + WR laminate, or winding laminate).



Enter material properties and partial influence factors A1 and A5. Validate the information and click "Insert" to create the laminate. Use "Edit" for later adjustments or "Delete" to remove it from the list.



The A-1 factor influences the minimum design factors for strength

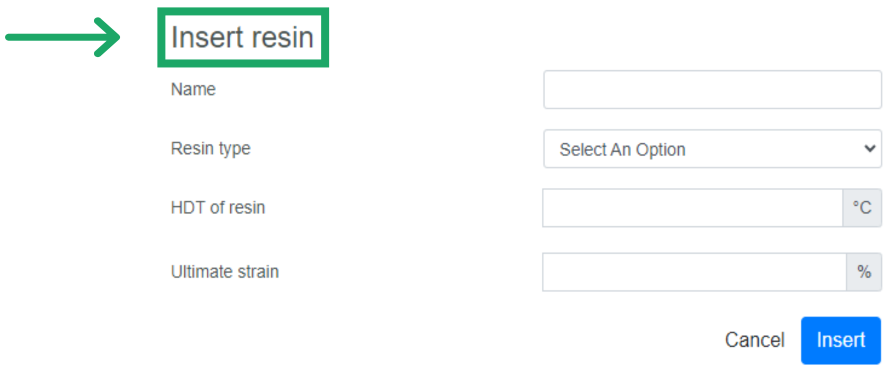
Amphora automatically compensates the A5-design factor when the minimum K- and F-factors are not met according to EN13121-3. and stability.

The partial material factors and material properties can be determined through the EN13121-3 or obtained through testing.

4.2. Adding a resin

On the Material List page, follow these steps to create a new resin:

1. Click "Create New Resin" and start by giving it a name.
2. Choose the resin type carefully; the accuracy of tank/silo calculations depends on the selected resin type.
3. After selecting the resin type and naming it, indicate the heat distortion temperature and ultimate strain, details that can be found in the resin's technical data sheets.
4. Click "Insert," and the new resin will be added to the Materials list. To make any changes, click "Edit" for quick edits or to modify any information about the resin.



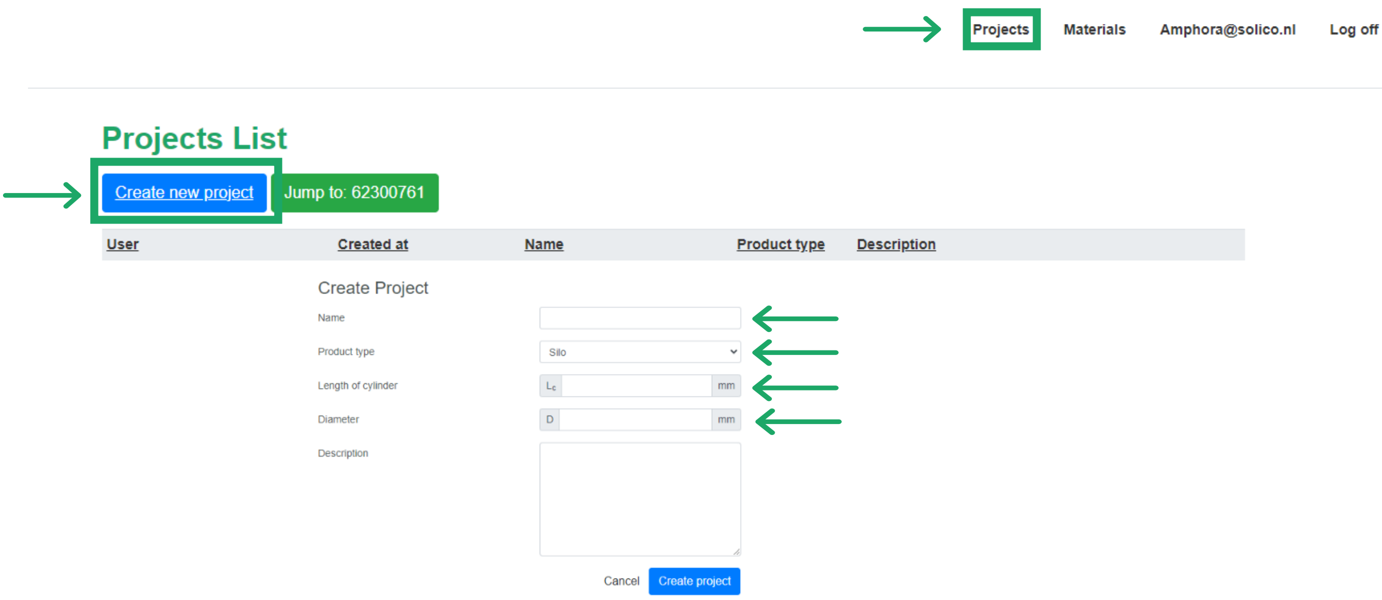
Please note that Amphora does not verify if the resin used aligns with EN13121-2. The user must ensure compliance between the resin of the liner and structural laminate. If information in EN13121-2 is insufficient, seek resin advice from your resin provider.

5. Projects

This chapter guides users through the process of generating a silo or tank calculation within the software. To start the calculation process, follow these steps:

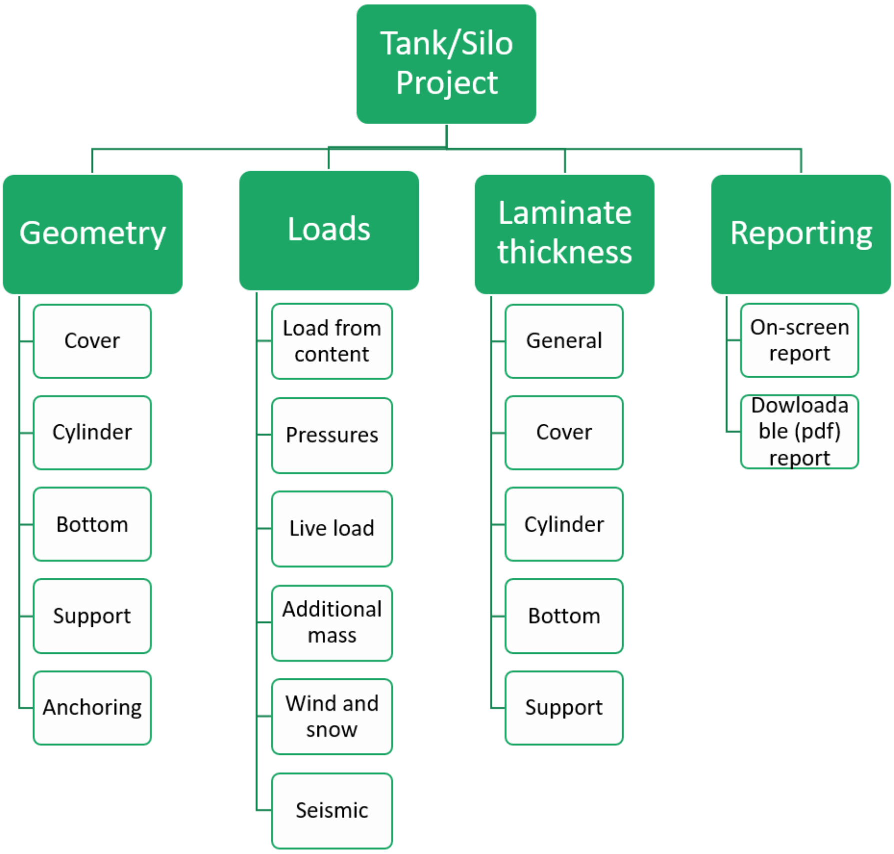
1. Go to the Project tab
2. Select "Create a New Project"
3. Provide a name, select the product type from the pull-down menu**, and input the cylinder's length and diameter
4. Click “Create Project”

** The available project types depend on your licences. If a product type in the list is unavailable to you, please contact your Amphora admin.



After successfully creating your project, the system will redirect you to the projects list page, where you can find your newly created project. To start working on it, click on the "edit" option.

Each user within an organisation can generate projects. Each of these projects has the same structure. So after clicking ‘edit’ the structure of the project looks like the figure below, in which the icons on the second row correspond with the tabs in the amphora program.



6. Silos

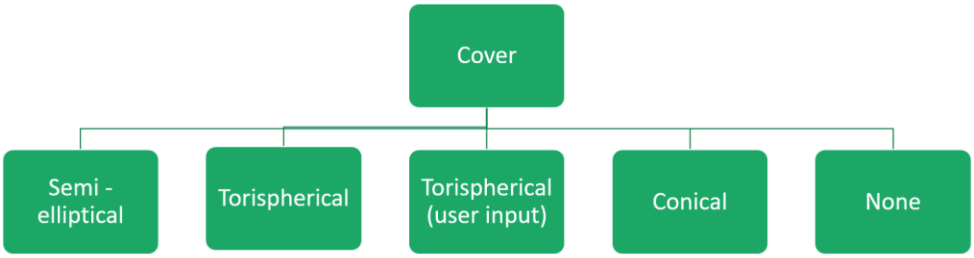
One of the project types available is a silo. A silo is a cylindrical storage vessel of dry bulk goods with a hopper bottom.

6.1. Geometry

First, establish the geometry of the tank or silo. The process always begins at the top of the structure, working our way down, starting with the construction of the cover.

6.1.1. Cover

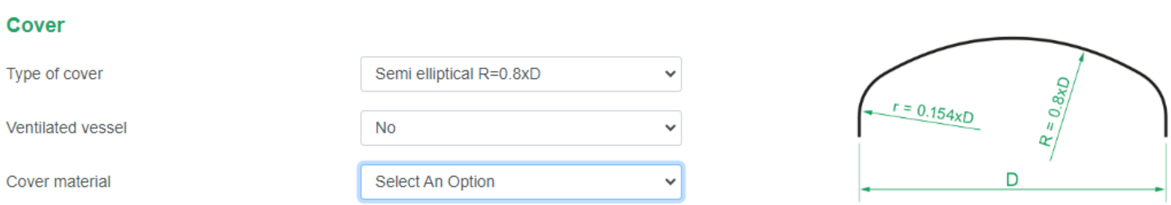
Start by selecting a cover type from the dropdown menu, which shows several geometric options, including the choice of having no cover.



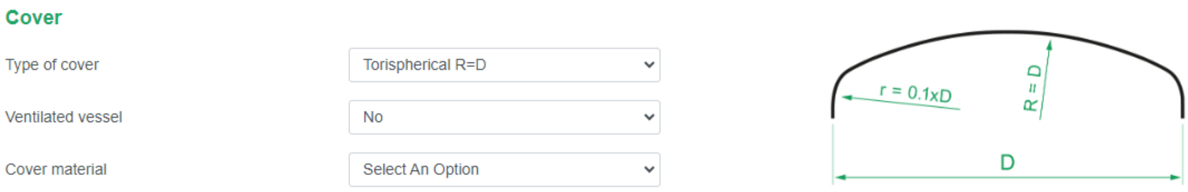
These options align with industry standards, and are presented below.

Subsequently, specify whether the vessel is ventilated. Indicate 'Yes' if there is a pipe allowing ventilation into the atmosphere or if a filter is present; otherwise, select 'No'. Finally, select the cover material. It is important to note that when adding materials, the material from which the cover is made can be specified.

<u>6.1.1.1. Semi Elliptical Cover</u>

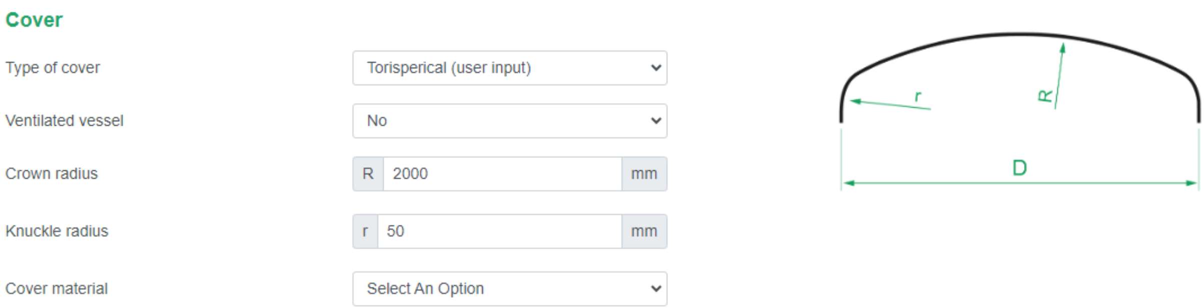


6.1.1.2. Torispherical Cover

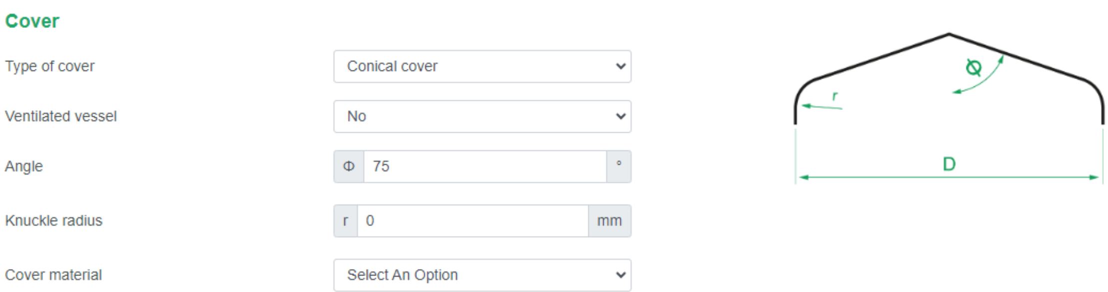


6.1.1.3. Torispherical Cover with user input

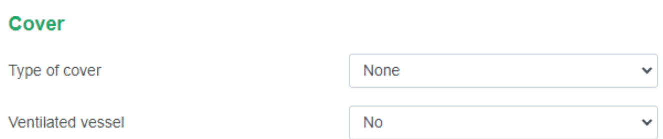
Use the ‘user input option’ for torispherical covers with deviating radius.



6.1.1.4. Conical Cover



6.1.1.5. No Cover

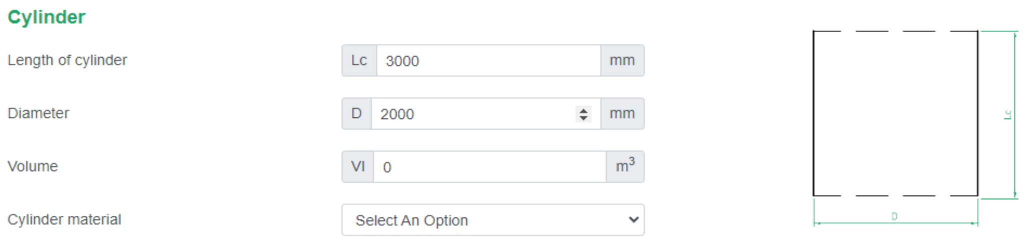


The selection of ‘no cover’ automatically affects the vacuum pressure in the tank, similar to the ‘ventilated’ option.

6.1.2. Cylinder

Proceed with entering the details about the cylinder. The length and diameter have already been pre-filled based on the information you provided during the project creation phase.

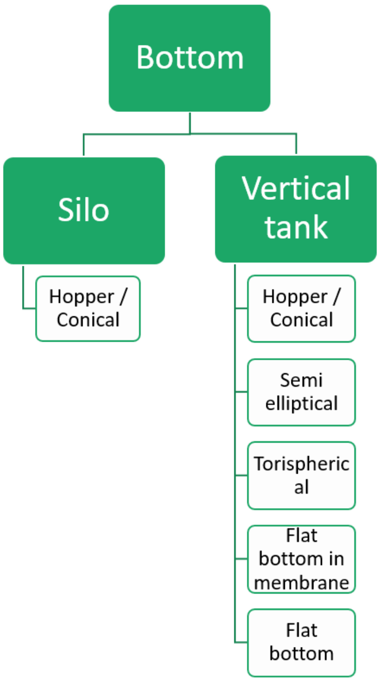
At this point, the focus is only on entering the used volume and select the cylinder material.



Note that Amphora automatically determines the number of sections to divide the cylinder. This is based on the ‘length of cylinder’.

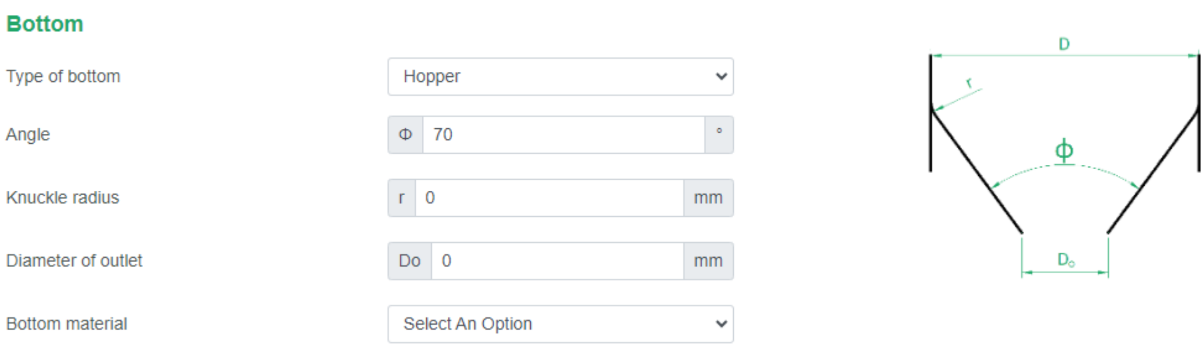
6.1.3. Bottom

In this section, provide information about the bottom of the vessel. The type of bottom can be selected, but available options depend on the type of project you are working on.



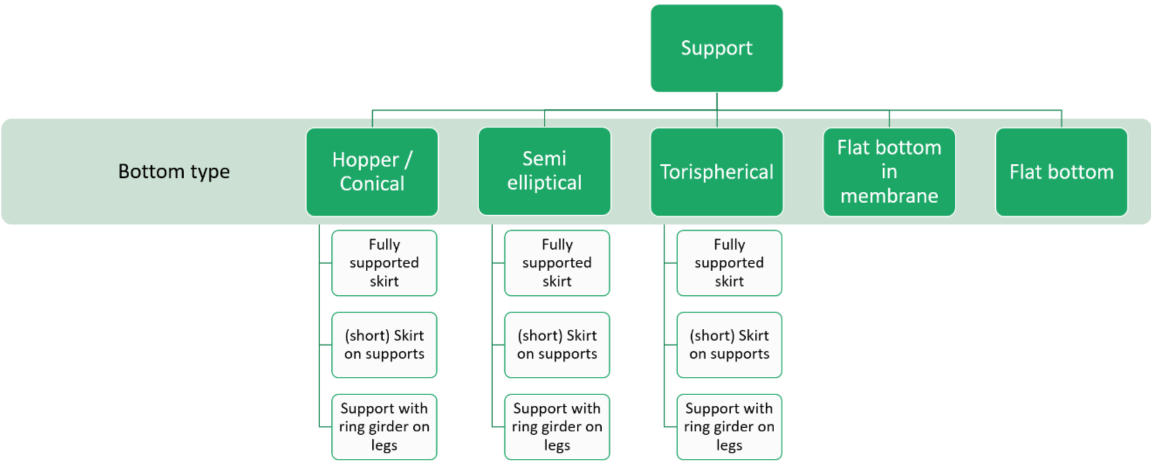
6.1.3.1. Hopper

! For silos, this is always a hopper bottom. Complete the fields for the angle of the cone, knuckle radius, diameter of the outlet, and choose the bottom material. It's important to note that hat the knuckle radius can also be zero if there is no knuckle radius.



6.1.4. Support

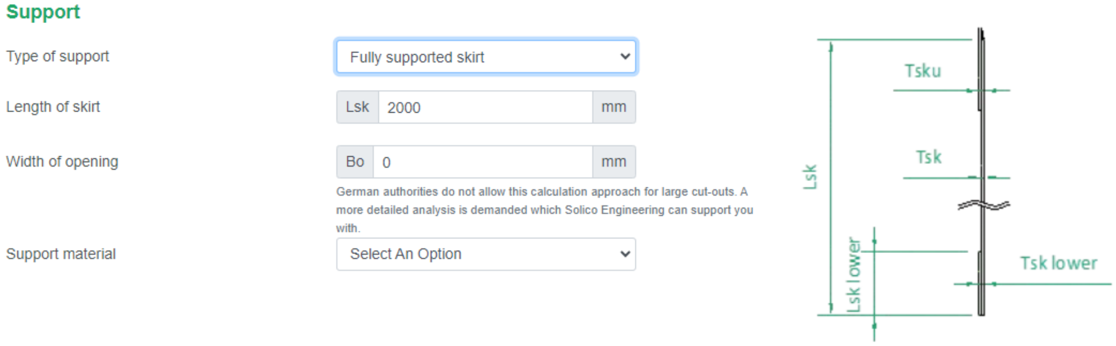
The support options change with the chosen product type and bottom type. Explore support options like skirt on supports, fully supported skirt, or support with a ring girder on legs.



Fill in details such as height, skirt length, opening width, and support material for the chosen support.

6.1.4.1. Fully supported skirt

This is a vessel on a skirt underneath the cylinder-bottom transition. This skirt is supported by the foundation over the full circumference.



When you select a fully supported skirt, an opening can be introduced. When an opening is present, enter the 'width of the opening', otherwise enter 0 to remove this option.

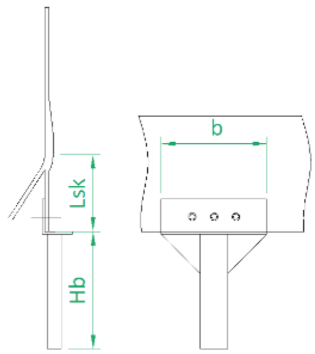
When an opening is present, you can also include the stiffness of the portal that reinforces the cut-out.

6.1.4.2. Skirt on supports

This is a vessel with a short skirt underneath the cylinder-bottom transition, supported by steel support legs or supported by a steel support structure.

Support

Type of support	Skirt on supports
Height above ground level	hb 0 mm
Length of skirt	Lsk 300 mm
Number of supports	Ns 4
Support width	b 300 mm
Support material	Select An Option

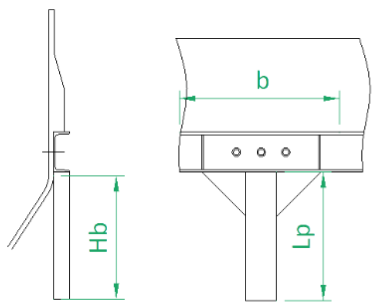


6.1.4.3. Support with ring girder on legs

This is a vessel without skirt, that has a (steel) UPN-ring bolted to the cylinder-bottom transition zone, which is in turn supported by steel support legs or supported by a steel support structure.

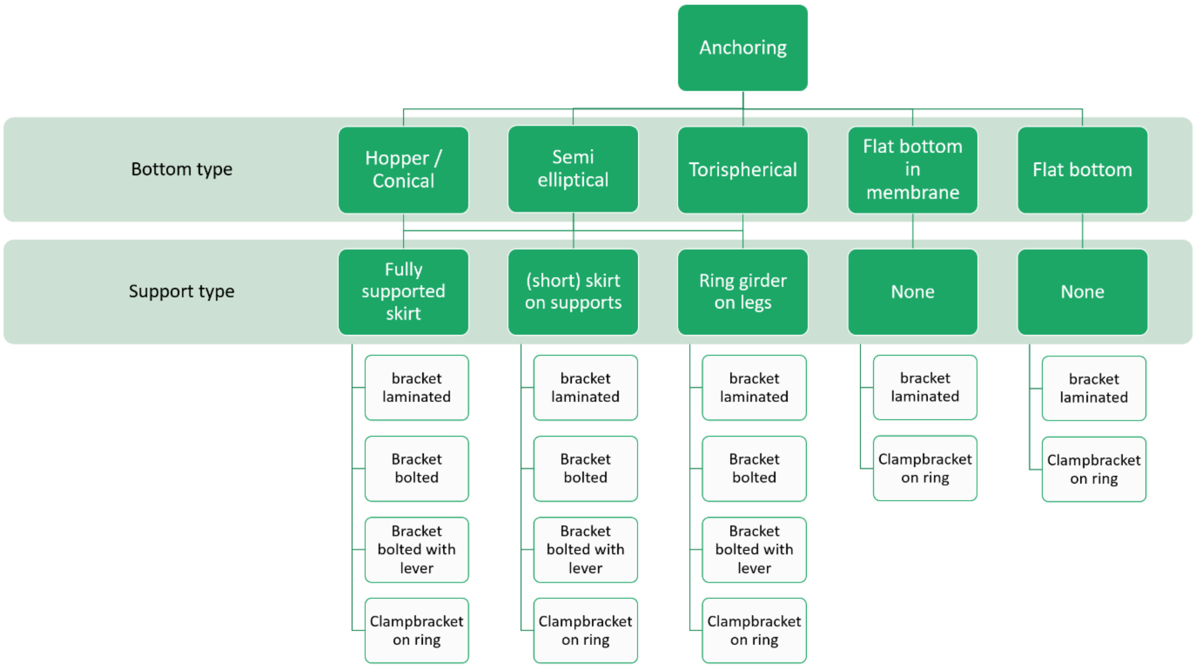
Support

Type of support	Support with ring girder on legs
Length of legs	Lp 2000 mm
Number of legs	Np 4
Support width per leg	b 300 mm
Support material	Select An Option



6.1.5. Anchoring

The available anchoring options depend on the support construction. Available options are: anchoring bracket laminated, anchoring bracket bolted, clamp bracket on ring, bolted through skirt with lever, or bolted to construction.

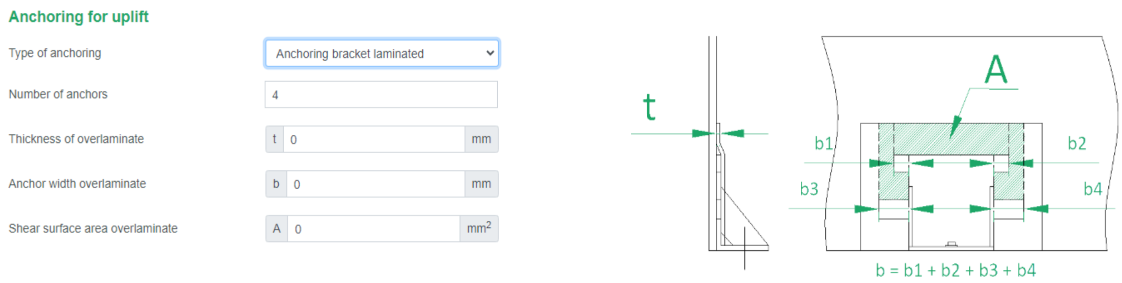


Enter the relevant information for the chosen anchoring option.

Note that the anchoring force calculated by Amphora is the vertical reaction force in the cylinder wall. The actual design force of the anchor bolt itself that connects the anchor to the vessels' foundation depends on the geometry of the used anchor bracket and has to be calculated separately.

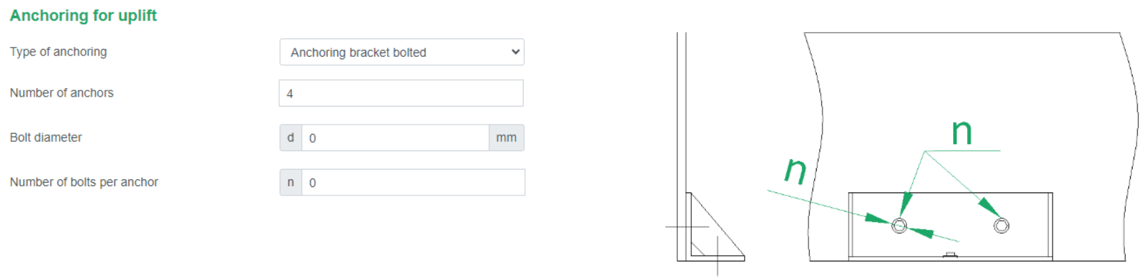
6.1.5.1. Anchoring bracket laminated

A pre-fabricated (steel) anchor, designed such that it can be connected to the vessel with a connection laminate.



6.1.5.2. Anchoring bracket bolted

A pre-fabricated (steel) anchor, bolted to the vessel.



6.1.5.3. Bolts through skirt with lever

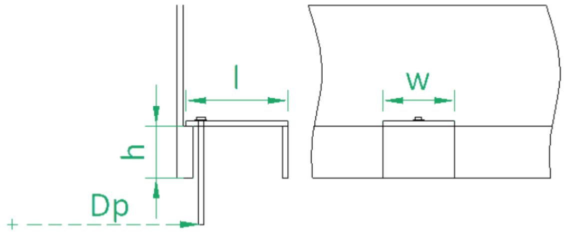
A pre-fabricated (steel) anchor with a certain eccentricity (= lever), bolted to the vessel.

6.1.5.4. Clampbracket on ring

The lower edge of the vessel is equipped with a ‘nose’, in combination with the (steel) clampbrackets this is the anchoring of the vessel.

Anchoring for uplift

Type of anchoring		Clampbracket on ring	
Number of anchors		4	
Pitch diameter of bolts	Dp	200	mm
Length of bracket	l	125	mm
Width of bracket	w	100	mm
Height of anchor/nose	h	0	mm



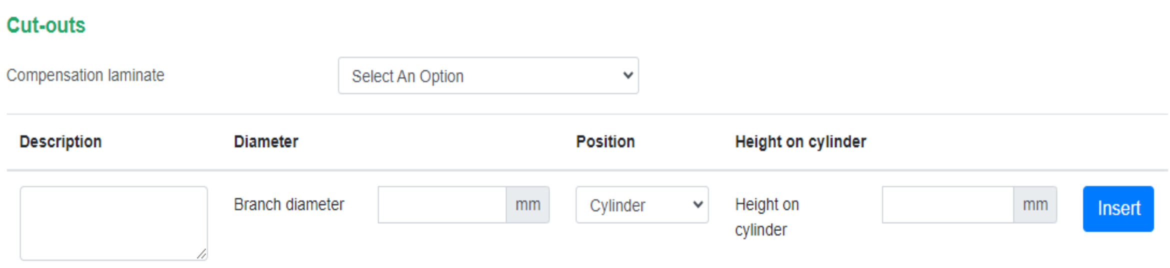
6.1.6. Cut-outs

The Cut-outs module serves to determine the thickness of the compensation laminate when incorporating cut-outs for nozzles or filter mounts into your design.

Each different cut-out can be given a name, and a diameter. The cut-outs can be placed in the cover, bottom, and the cylinder. In case the cut-out is located in the cylinder, the height of the cut-out along the cylinder has to be provided as well.

It's essential to be aware that, within this module, Amphora exclusively considers the loads present in the vessel and the hydrostatic pull-out pressure. Amphora does not factor in any external loads on the nozzle.

> ! Amphora does not take into account any external nozzle loads.



6.2. Loads

Once the geometry of the tank/silo is complete, the loads can start being defined. Once the geometry is completed, click on the 'Loads' header, after you confirmed your geometry by clicking 'update'.

6.2.1. Load from content

Begin by specifying the medium type and its dedicated density. Dry bulk mediums require unique pressure and wall friction coefficients. The default values in Amphora are the conservative values according to the EN1991-4. Other values can be entered, based on testing values or the EN 1991-4 standard.

Input the bottom load magnifying factor and refer to "more info" if needed.

Finally, enter the design temperature.

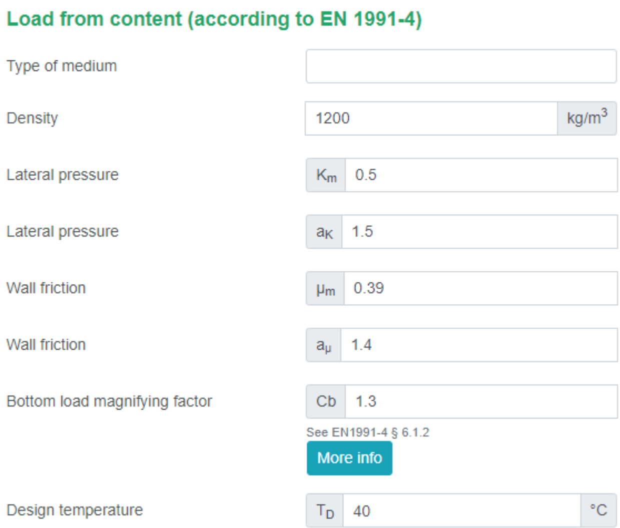


Table E.1: Particulate solids properties

Type of particulate solid [d, e]	Unit weight [b] γ		Angle of repose ϕ_r	Angle of internal friction ϕ_i		Lateral pressure ratio K		Wall friction coefficient [c] μ ($\mu = \tan \phi_w$)				Patch load solid reference factor C_{op}
	γ_l	γ_u	ϕ_r	ϕ_{im}	a_ϕ	K_m	a_K	Wall type D1	Wall type D2	Wall type D3	a_μ	
	Lower	Upper		Mean	Factor	Mean	Factor	Mean	Mean	Mean	Factor	
	kN/m³	kN/m³	degrees	degrees								
Default material [a]	6,0	22,0	40	35	1,3	0,50	1,5	0,32	0,39	0,50	1,40	1,0
Aggregate	17,0	18,0	36	31	1,16	0,52	1,15	0,39	0,49	0,59	1,12	0,4
Alumina	10,0	12,0	36	30	1,22	0,54	1,20	0,41	0,46	0,51	1,07	0,5
Animal feed mix	5,0	6,0	39	36	1,08	0,45	1,10	0,22	0,30	0,43	1,28	1,0
Animal feed pellets	6,5	8,0	37	35	1,06	0,47	1,07	0,23	0,28	0,37	1,20	0,7
Barley ✪	7,0	8,0	31	28	1,14	0,59	1,11	0,24	0,33	0,48	1,16	0,5
Cement	13,0	16,0	36	30	1,22	0,54	1,20	0,41	0,46	0,51	1,07	0,5
Cement clinker ‡	15,0	18,0	47	40	1,20	0,38	1,31	0,46	0,56	0,62	1,07	0,7
Coal ✪	7,0	10,0	36	31	1,16	0,52	1,15	0,44	0,49	0,59	1,12	0,6
Coal, powdered ✪	6,0	8,0	34	27	1,26	0,58	1,20	0,41	0,51	0,56	1,07	0,5
Coke	6,5	8,0	36	31	1,16	0,52	1,15	0,49	0,54	0,59	1,12	0,6
Flyash	8,0	15,0	41	35	1,16	0,46	1,20	0,51	0,62	0,72	1,07	0,5
Flour ✪	6,5	7,0	45	42	1,06	0,36	1,11	0,24	0,33	0,48	1,16	0,6
Iron ore pellets	19,0	22,0	36	31	1,16	0,52	1,15	0,49	0,54	0,59	1,12	0,5
Lime, hydrated	6,0	8,0	34	27	1,26	0,58	1,20	0,36	0,41	0,51	1,07	0,6
Limestone powder	11,0	13,0	36	30	1,22	0,54	1,20	0,41	0,51	0,56	1,07	0,5
Maize ✪	7,0	8,0	35	31	1,14	0,53	1,14	0,22	0,36	0,53	1,24	0,9
Phosphate	16,0	22,0	34	29	1,18	0,56	1,15	0,39	0,49	0,54	1,12	0,5
Potatoes	6,0	8,0	34	30	1,12	0,54	1,11	0,33	0,38	0,48	1,16	0,5
Sand	14,0	16,0	39	36	1,09	0,45	1,11	0,38	0,48	0,57	1,16	0,4
Slag clinkers	10,5	12,0	39	36	1,09	0,45	1,11	0,48	0,57	0,67	1,16	0,6
Soya beans	7,0	8,0	29	25	1,16	0,63	1,11	0,24	0,38	0,48	1,16	0,5
Sugar ✪	8,0	9,5	38	32	1,19	0,50	1,20	0,46	0,51	0,56	1,07	0,4
Sugarbeet pellets	6,5	7,0	36	31	1,16	0,52	1,15	0,35	0,44	0,54	1,12	0,5
Wheat ✪	7,5	9,0	34	30	1,12	0,54	1,11	0,24	0,38	0,57	1,16	0,5

NOTE Where this table does not contain the material to be stored, testing should be undertaken.

[a] For situations where it is difficult to justify the cost of testing, because the cost implications of using a wide property range for the design are minor, the properties of the "default material" may be used. For small installations, these properties may be adequate. However, they will lead to very uneconomic designs for large silos, and testing should always be preferred.

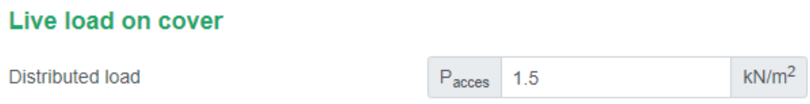
[b] The unit weight of the solid γ_u is the upper characteristic value, to be used for all calculations of actions. The lower characteristic value γ_l is provided in Table E.1 to assist in estimating the required volume of a silo that will have a defined capacity.

[c] Effective wall friction for wall Type D4 (corrugated wall) may be found using the method defined in Annex D, D.2.

[d] Solids in this table that are known to be susceptible to dust explosion are identified by the symbol ✪

[e] Solids that are susceptible to mechanical interlocking are identified by the symbol ‡

6.2.2. Pressure



Enter the design pressure and design vacuum. Indicate whether it is a short term or long term load using the dropdown menu. For additional details, click on "more info". If no pressures are provided, the EN-standard obliges to consider a minimum internal and external pressure, what Amphora does automatically.

Consider charging and discharging by filling in zero to automatically adhere to standards. For silos with features like an explosion hatch, enter the maximum reduced explosion pressure as needed.

! Amphora will always consider the minimum pressures prescribed by the standard, even when the pressures are set to zero by the user.

6.2.3. Live load

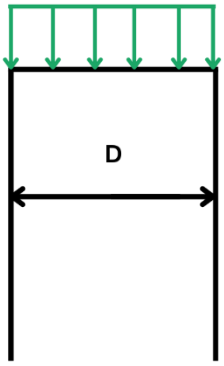
Just like for the pressures, the standard describes the minimum value which is always considered. If nothing is filled in, the minimum value described in the standard is applied.

6.2.4. Additional mass

There is a possibility to add additional masses, depending on the location. Additional masses can be located on the cover, cylinder, hand railing, ladder or hopper outlet.

6.2.4.1. Additional Mass on cover

On cover

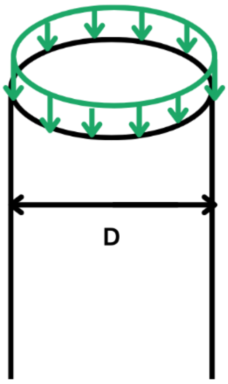


$W_{cover\ [kg]}$ = load is distributed over cover surface

E.g.: $\dfrac{500\ kg}{\pi \cdot \left(\frac{D}{2}\right)^2}$

6.2.4.2. Additional Mass on top of cylinder

On top of cylinder

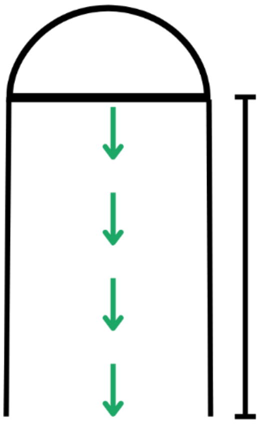


$Q_{cylinder\ [kg]}$ = load is distributed over cylinder circumference

E.g.: $\dfrac{500kg}{\pi \cdot D_{cylinder}}$

6.2.4.3. Additional Mass on outside wall

On outside wall

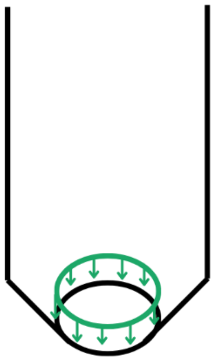


$W_{cylinder\ [kg/m]}$ = distributed load over cylinder length

E.g. : 500kg/m x l l = ... kg

6.2.4.4. Additional Mass on outlet of hopper

On outlet of hopper

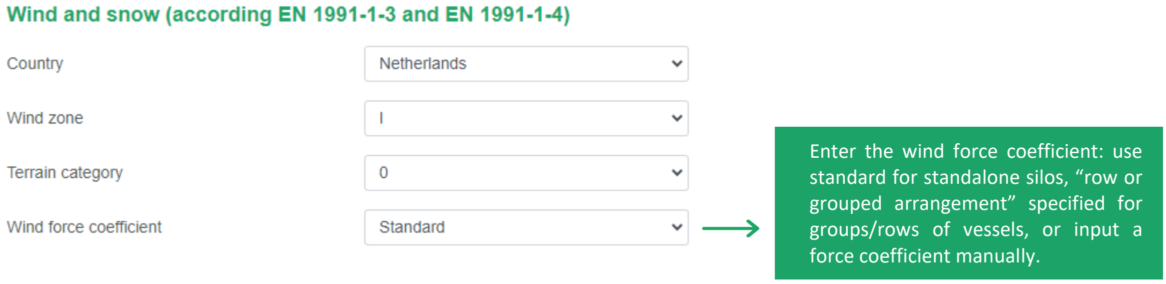


$W_{hopper\ [kg]}$ = load is distributed over edge of outlet

E.g. : $\frac{500kg}{\pi \cdot D_{hopper\ outlet}}$

6.2.5. Wind and snow

Currently Amphora can automatically determine the wind and snow load for the Benelux, Germany, France and Italy. These loads are compliant with the national annexes of the EN1991-1-3 and EN1991-1-4 of each respective country.
To use this functionality a country, a wind zone, a terrain category and a snow zone has to be selected from the pull-down menu, based on the delivery location of your vessel.



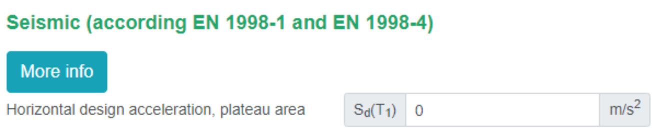
If your vessel is located outside the available countries in Amphora, you can select the option "user input" from the "country" pull-down menu. This allows you to fill in the values of the extreme wind pressure and snow load on the ground for the location. These pressures can be calculated according to the national annex of the EN1991-1-3 and EN1991-1-4 of the specific country.

6.2.6. Seismic Loads

Depending on the location of your vessel, the seismic loads in accordance with the EN 1998 standard can be entered.

You need to calculate/enter the horizontal design acceleration in the plateau area of the response spectrum. Based on the location, the locations soil type and the importance class of your vessel.

This is a conservative approach.



If you know the eigenfrequency of your system, a different value can be entered, based on your calculations.

This is a complex calculation that hinges on various factors. For additional assistance, click on "more info.", or contact the amphora admin if Solico’s assistance is required.

6.3. Laminate thickness

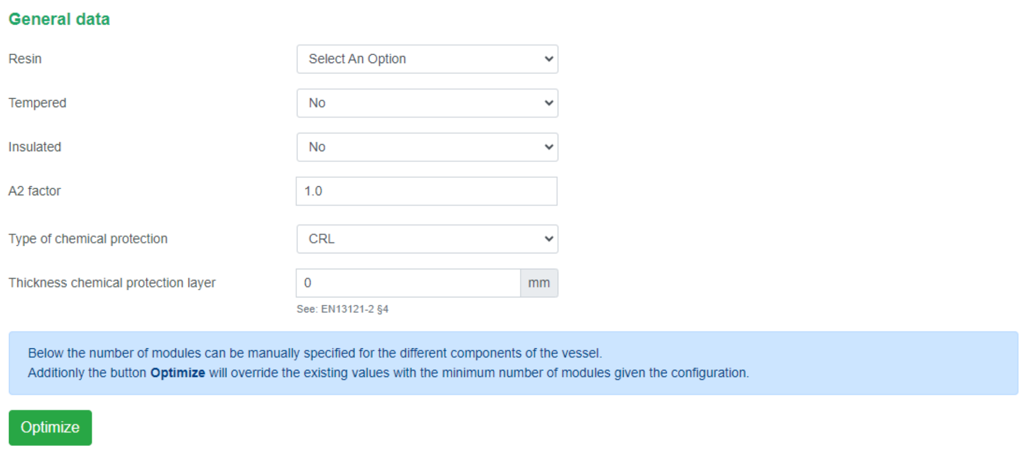
Once the loads of the tank/silo are complete, the laminates can be defined. Click on the 'Laminate thickness' header, after you confirmed your loads by clicking 'update'.

6.3.1. General

Start by entering general data, selecting the resin from your database, and indicating whether the silo is tempered/cured and insulated (yes/no impacts self-weight for structural calculations, and the calculation of the A_3-factor).

Address the A_2-factor for chemical resistance, typically set to one for dry bulk materials (silos), but depending on the type of medium for tanks storing liquids.

The type and thickness of the chemical protection barrier has to be added. Choose between a single protection layer (SPL), a chemical barrier layer (CBL) and a thermoplastic protection layer (TPL). The type and required thickness of this layer is prescribed by EN13121-2, otherwise a resin advice has to be obtained through your resin provider.



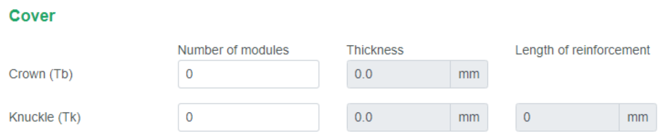
After entering all previous data, there are 2 ways to determine the required structural laminate thicknesses for your project:

1. Specify the number of modules yourself, and click 'analyse'
2. or let the Amphora algorithm determine the optimum thicknesses by clicking "optimize

! Amphora only calculates the structural thicknesses. All thicknesses visible in tables, determined by Amphora's optimisation routine, or entered manually are structural thicknesses, EXCLUDING the required thickness for the chemical protection layer.

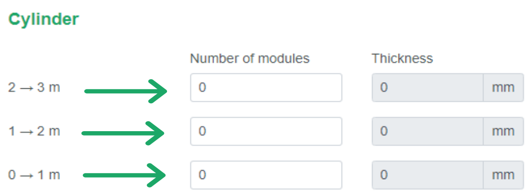
6.3.2. Cover

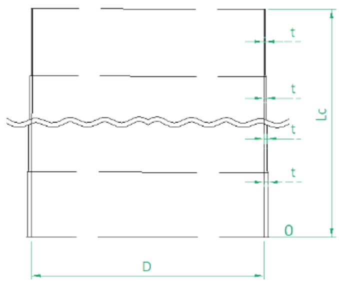
The cover has two sections: the crown and the knuckle. Input the number of modules, representing the number of layers you construct. Thickness is automatically calculated based on the module thicknesses listed in your material database.



6.3.3. Cylinder

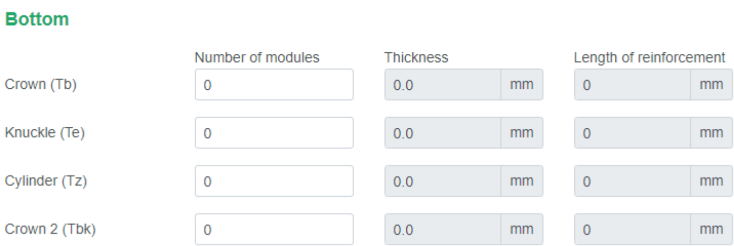
Amphora automatically divides the cylinder into slices (or sections), the length of a slice depends on the total length of the cylinder. Adjust the number of laminate modules in each section to control the structural thickness.

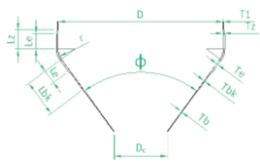




6.3.4. Bottom

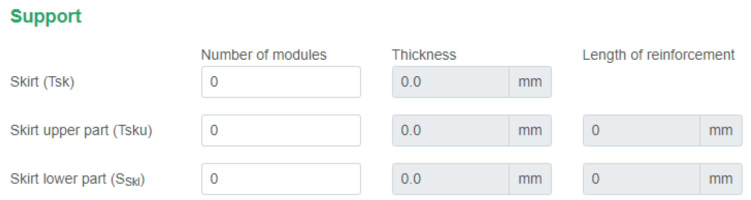
Start with the crown thickness and input the number of modules for each hopper section, as indicated in the figure.





6.3.5. Support

Proceed to input support and anchoring for uplift, dependent on the support type chosen earlier. For the skirt, enter the number of modules for the skirt, skirt upper part, and skirt lower part. Anchoring for uplift may not be applicable for some silo's, contingent on the selected support type during geometry calculations.



7. Vertical Tank

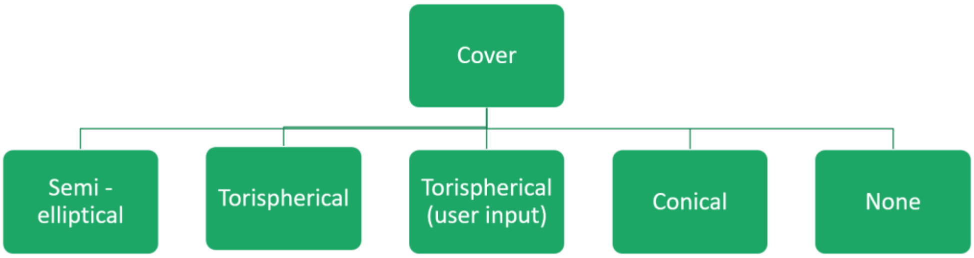
One of the project types available is vertical tank. A vertical tank is in essence a cylindrical storage vessel of liquid mediums.

7.1. Geometry

First, establish the geometry of the tank or silo. The process always begins at the top of the structure, working our way down, starting with the construction of the cover.

7.1.1. Cover

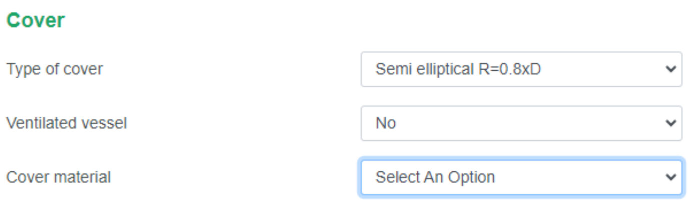
Start by selecting a cover type from the dropdown menu, which shows several geometric options, including the choice of having no cover.

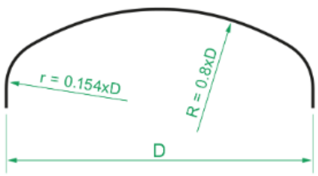


These options align with industry standards, and are presented below.

Subsequently, specify whether the vessel is ventilated. Indicate 'Yes' if there is a pipe allowing ventilation into the atmosphere or if a filter is present; otherwise, select 'No'. Finally, select the cover material. It is important to note that when adding materials, the material from which the cover is made can be specified.

7.1.1.1. Semi Elliptical Cover

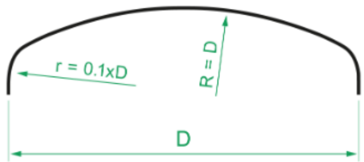




7.1.1.2. Torispherical Cover

Cover

Type of cover	Torispherical R=D
Ventilated vessel	No
Cover material	Select An Option

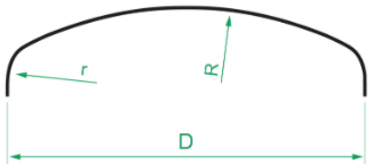


7.1.1.3. Torispherical Cover with user input

Use the ‘user input option’ for torispherical covers with deviating radii.

Cover

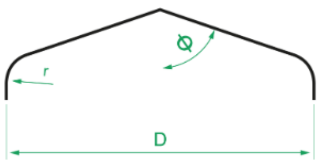
Type of cover	Torisperical (user input)
Ventilated vessel	No
Crown radius	R 2000 mm
Knuckle radius	r 50 mm
Cover material	Select An Option



7.1.1.4. Conical Cover

Cover

Type of cover	Conical cover
Ventilated vessel	No
Angle	Φ 75 °
Knuckle radius	r 0 mm
Cover material	Select An Option



7.1.1.5. No Cover

Cover

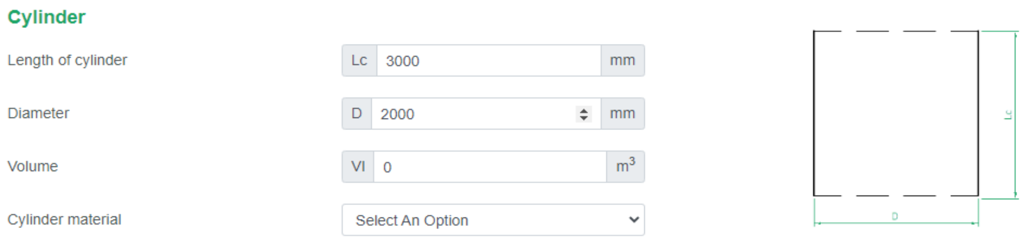
Type of cover	None
Ventilated vessel	No

The selection of ‘no cover’ automatically affects the vacuum pressure in the tank, similar to the ‘ventilated’ option.

7.1.2. Cylinder

Proceed with entering the details about the cylinder. The length and diameter have already been pre-filled based on the information you provided during the project creation phase.

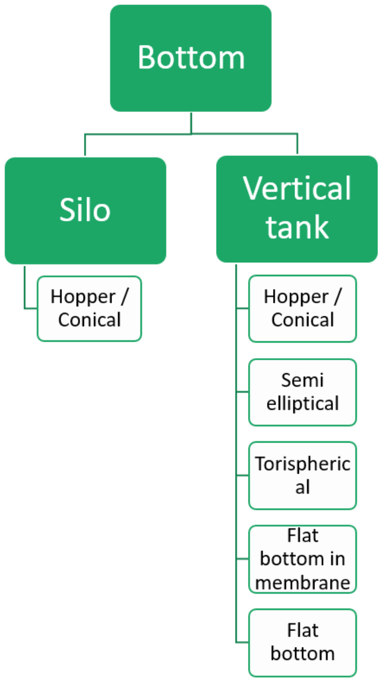
At this point, the focus is only on entering the used volume and select the cylinder material.



Note that Amphora automatically determines the number of sections to divide the cylinder. This is based on the 'length of cylinder'.

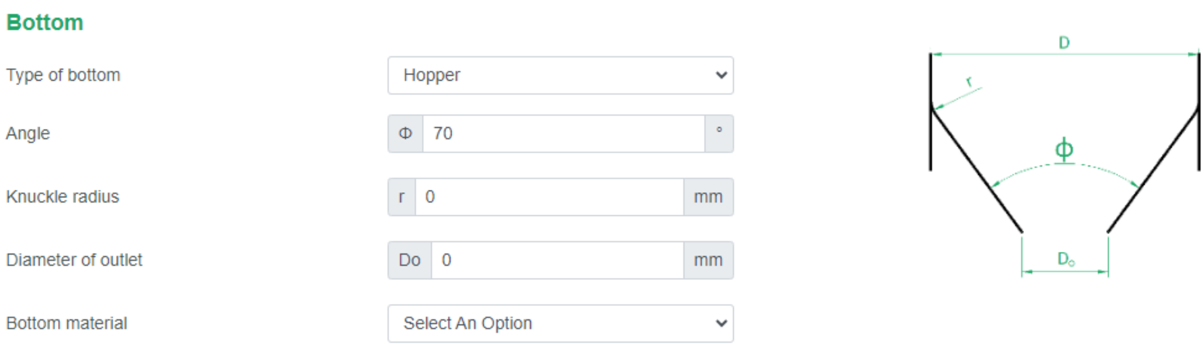
7.1.3. Bottom

In this section, provide information about the bottom of the vessel. The type of bottom can be selected, but available options depend on the type of project you are working on.



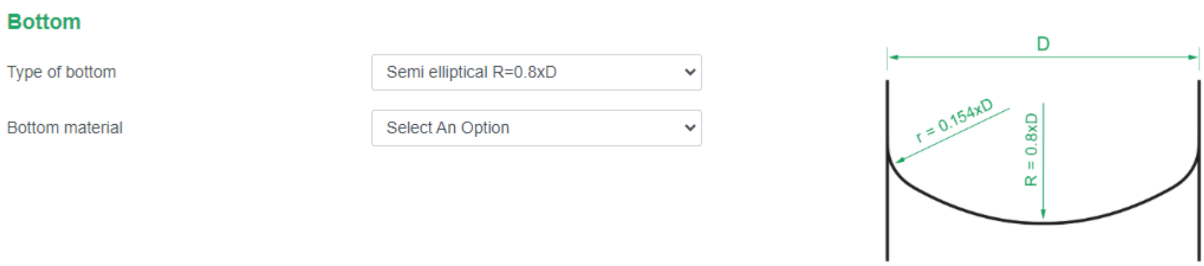
7.1.3.1. Hopper

Complete the fields for the angle of the cone, knuckle radius, diameter of the outlet, and choose the bottom material. It's important to note that hat the knuckle radius can also be zero if there is no knuckle radius.



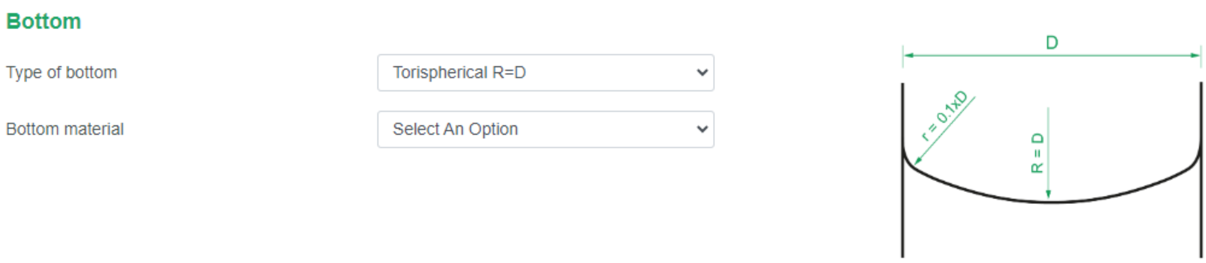
7.1.3.2. Semi elliptical bottom

Choose the bottom material.



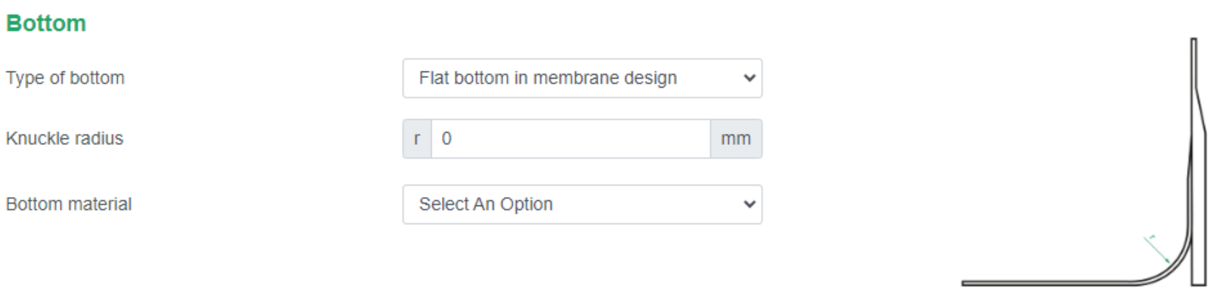
7.1.3.3. Torishpherical bottom

Choose the bottom material.



7.1.3.4. Flat bottom in membrane design

Complete the fields for the radius of the knuckle and choose the bottom material.

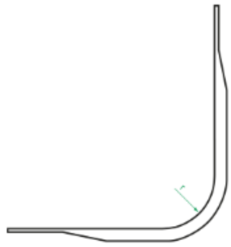


7.1.3.5. Flat bottom with knuckle

Complete the fields for the radius of the knuckle and choose the bottom material.

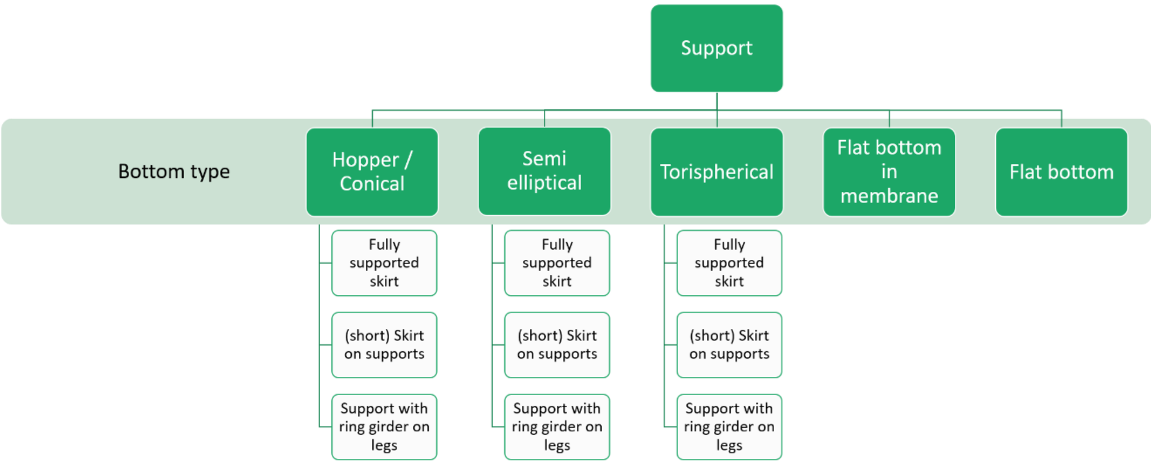
Bottom

Type of bottom	Flat bottom with knuckle
Knuckle radius	r 0 mm
Bottom material	Select An Option



7.1.4. Support

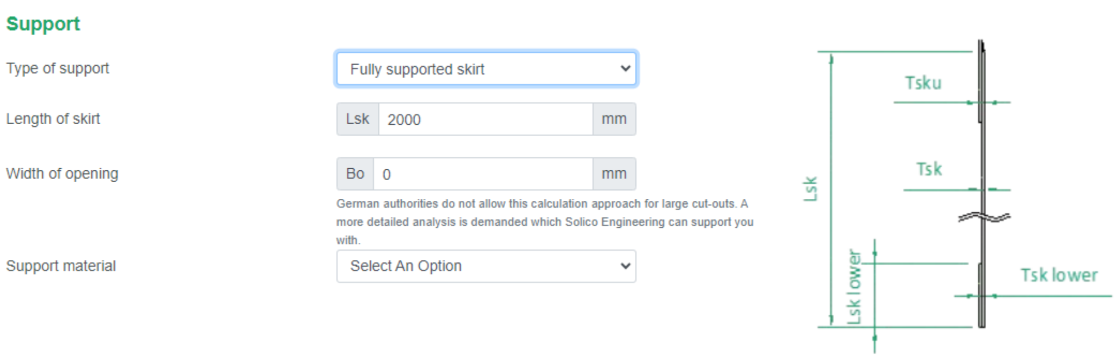
The support options change with the chosen product type and bottom type. Explore support options like skirt on supports, fully supported skirt, or support with a ring girder on legs.



Fill in details such as height, skirt length, opening width, and support material for the chosen support.

7.1.4.1. Fully supported skirt

This is a vessel on a skirt underneath the cylinder-bottom transition. This skirt is supported by the foundation over the full circumference.



When you select a fully supported skirt, an opening can be introduced. When an opening is present, enter the ‘width of the opening’, otherwise enter 0 to remove this option.

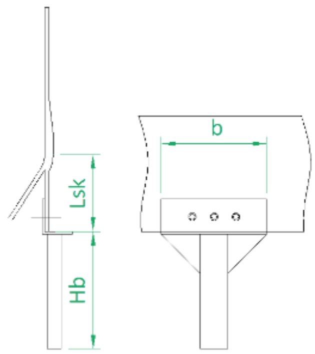
When an opening is present, you can also include the stiffness of the portal that reinforces the cut-out.

7.1.4.2. Skirt on supports

This is a vessel with a short skirt underneath the cylinder-bottom transition, supported by steel support legs or supported by a steel support structure.

Support

Type of support		Skirt on supports	
Height above ground level	hb	0	mm
Length of skirt	Lsk	300	mm
Number of supports	Ns	4	
Support width	b	300	mm
Support material		Select An Option	

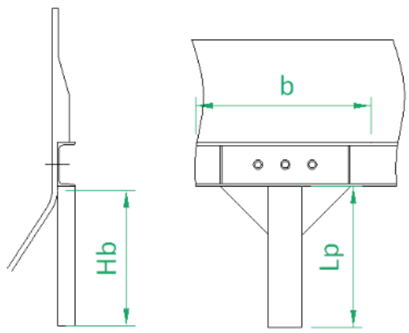


7.1.4.3. Support with ring girder on legs

This is a vessel without skirt, that has a (steel) UPN-ring bolted to the cylinder-bottom transition zone, which is in turn supported by steel support legs or supported by a steel support structure.

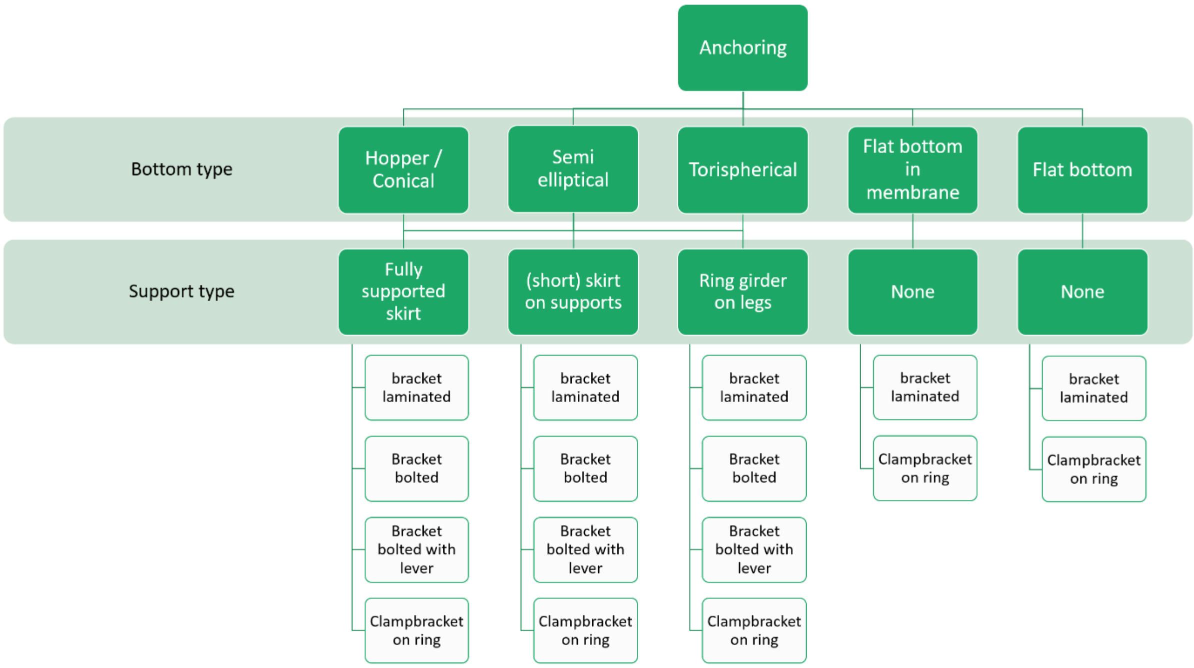
Support

Type of support		Support with ring girder on legs	
Length of legs	Lp	2000	mm
Number of legs	Np	4	
Support width per leg	b	300	mm
Support material		Select An Option	



7.1.5. Anchoring

The available anchoring options depend on the support construction. Available options are: anchoring bracket laminated, anchoring bracket bolted, clamp bracket on ring, bolted through skirt with lever, or bolted to construction.

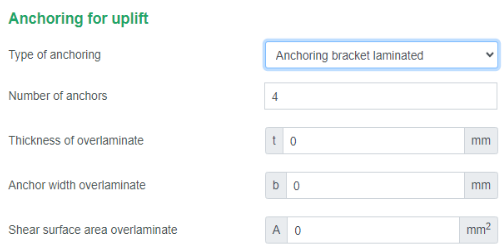


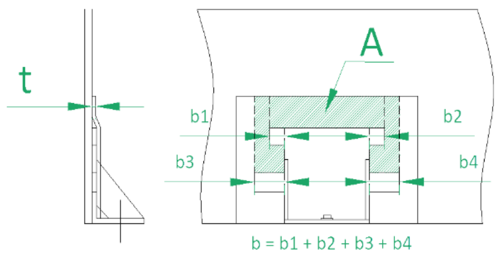
Enter the relevant information for the chosen anchoring option.

Note that the anchoring force calculated by Amphora is the vertical reaction force in the cylinder wall. The actual design force of the anchor bolt itself that connects the anchor to the vessels' foundation depends on the geometry of the used anchor bracket and has to be calculated separately.

7.1.5.1. Anchoring bracket laminated

A pre-fabricated (steel) anchor, designed such that it can be connected to the vessel with a connection laminate.



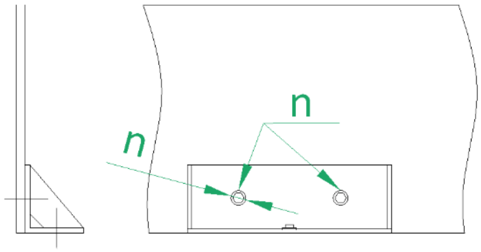


7.1.5.2. Anchoring bracket bolted

A pre-fabricated (steel) anchor, bolted to the vessel.

Anchoring for uplift

Type of anchoring	Anchoring bracket bolted
Number of anchors	4
Bolt diameter	d 0 mm
Number of bolts per anchor	n 0

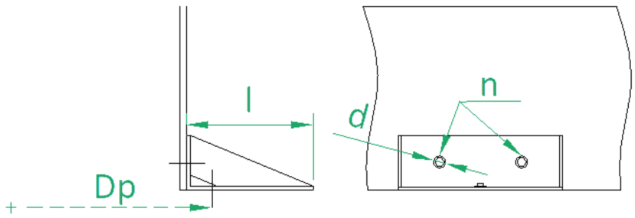


7.1.5.3. Bolts through skirt with lever

A pre-fabricated (steel) anchor with a certain eccentricity (= lever), bolted to the vessel.

Anchoring for uplift

Type of anchoring	Bolts through skirt with lever
Number of anchors	4
Bolt diameter	d 0 mm
Pitch diameter of bolts	Dp 200 mm
Length of bracket	l 125 mm
Number of bolts per anchor	n 0

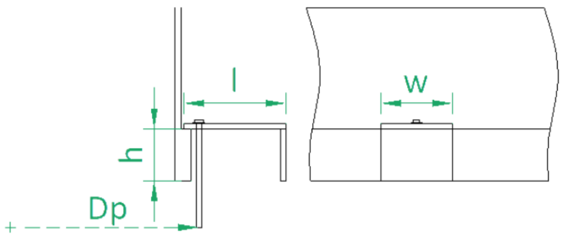


7.1.5.4. Clampbracket on ring

The lower edge of the vessel is equipped with a 'nose', in combination with the (steel) clampbrackets this is the anchoring of the vessel.

Anchoring for uplift

Type of anchoring	Clampbracket on ring
Number of anchors	4
Pitch diameter of bolts	Dp 200 mm
Length of bracket	l 125 mm
Width of bracket	w 100 mm
Height of anchor/nose	h 0 mm



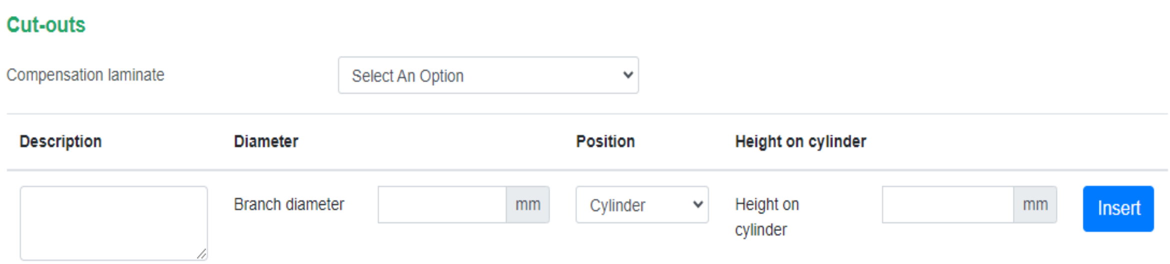
7.1.6. Cut-outs

The Cut-outs module serves to determine the thickness of the compensation laminate when incorporating cut-outs for nozzles or filter mounts into your design.

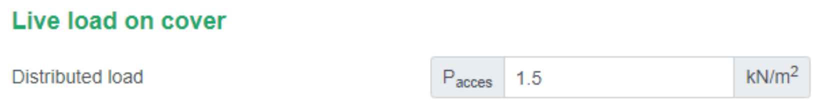
Each different cut-out can be given a name, and a diameter. The cut-outs can be placed in the cover, bottom, and the cylinder. In case the cut-out is located in the cylinder, the height of the cut-out along the cylinder has to be provided as well.

It's essential to be aware that, within this module, Amphora exclusively considers the loads present in the vessel and the hydrostatic pull-out pressure. Amphora does not factor in any external loads on the nozzle.

! Amphora does not take into account any external nozzle loads.



7.2. Loads



Once the geometry of the tank/silo is complete, the loads can start being defined. Once the geometry is completed, click on the ‘Loads’ header, after you confirmed your geometry by clicking ‘update’.

7.2.1. Load from content

Begin by specifying the medium type, its density, and the design temperature

7.2.2. Pressure

Enter the design pressure and design vacuum. Indicate whether it is a short term or long term load using the dropdown menu. For additional details, click on "more info". If no pressures are provided, the EN-standard obliges to consider a minimum internal and external pressure, what Amphora does automatically.

Consider charging and discharging by filling in zero to automatically adhere to standards. For silos with features like an explosion hatch, enter the maximum reduced explosion pressure as needed.

! Amphora will always consider the minimum pressures prescribed by the standard, even when the pressures are set to zero by the user.

7.2.3. Live load

Just like for the pressures, the standard describes the minimum value which is always considered. If nothing is filled in, the minimum value described in the standard is applied.

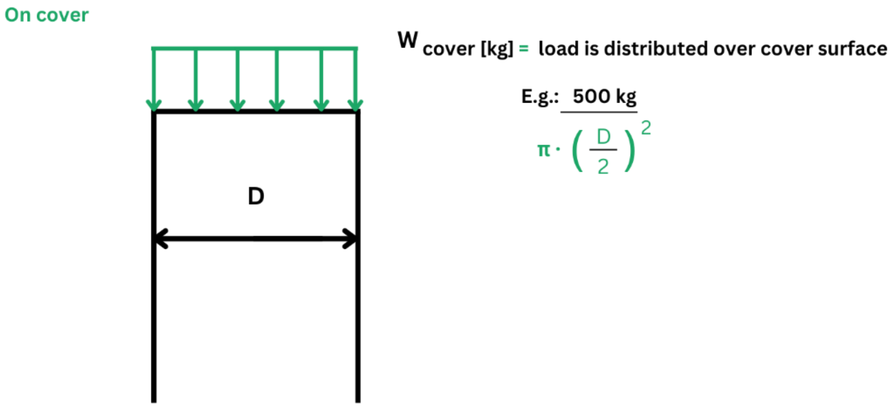
7.2.4. Additional mass

There is a possibility to add additional masses, depending on the location. Additional masses can be located on the cover, cylinder, hand railing, ladder or hopper outlet.

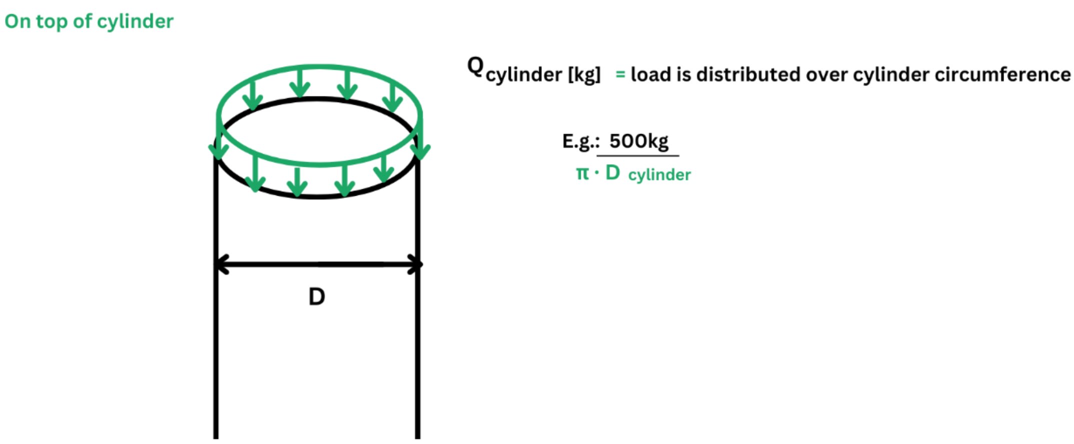
Additional mass

On cover	W_{cover}	0	kg
On top of cylinder	$Q_{cylinder}$	0	kg
On cylinder wall	$W_{cylinder}$	0	kg/m
On outlet of hopper	W_{hopper}	0	kg

7.2.4.1. Additional Mass on cover

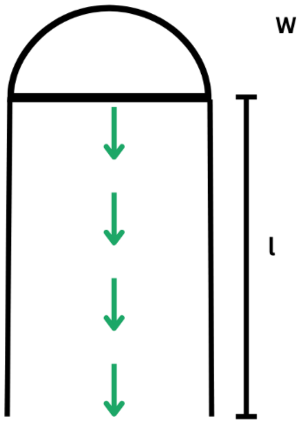


7.2.4.2. Additional Mass on top of cylinder



7.2.4.3. Additional Mass on outside wall

On outside wall

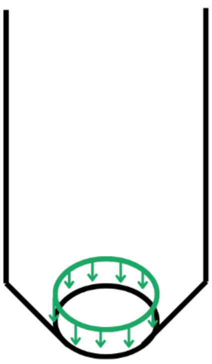


W cylinder [kg/m] = distributed load over cylinder length

E.g. : 500kg/m x l l = ... kg

7.2.4.4. Additional Mass on outlet of hopper

On outlet of hopper

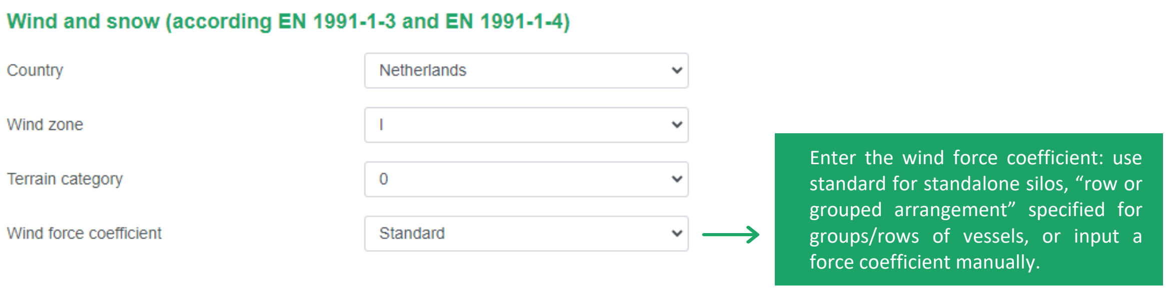


W hopper [kg] = load is distributed over edge of outlet

$$\frac{\text{E.g. : 500kg}}{\pi \cdot D_{\text{hopper outlet}}}$$

7.2.5. Wind and snow

Currently Amphora can automatically determine the wind and snow load for the Benelux, Germany, France and Italy. These loads are compliant with the national annexes of the EN1991-1-3 and EN1991-1-4 of each respective country.
To use this functionality a country, a wind zone, a terrain category and a snow zone has to be selected from the pull-down menu, based on the delivery location of your vessel.



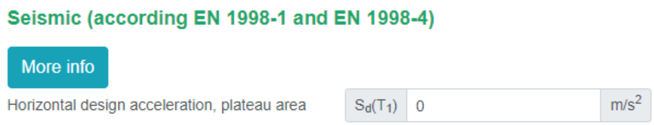
If your vessel is located outside the available countries in Amphora, you can select the option “user input” from the “country” pull-down menu. This allows you to fill in the values of the extreme wind pressure and snow load on the ground for the location. These pressures can be calculated according to the national annex of the EN1991-1-3 and EN1991-1-4 of the specific country.

7.2.6. Seismic Loads

Depending on the location of your vessel, the seismic loads in accordance with the EN 1998 standard can be entered.

You need to calculate/enter the horizontal design acceleration in the plateau area of the response spectrum. Based on the location, the locations soil type and the importance class of your vessel.

This is a conservative approach.



If you know the eigenfrequency of your system, a different value can be entered, based on your calculations.

This is a complex calculation that hinges on various factors. For additional assistance, click on "more info.", or contact the amphora admin if Solico’s assistance is required.

7.3. Laminate thickness

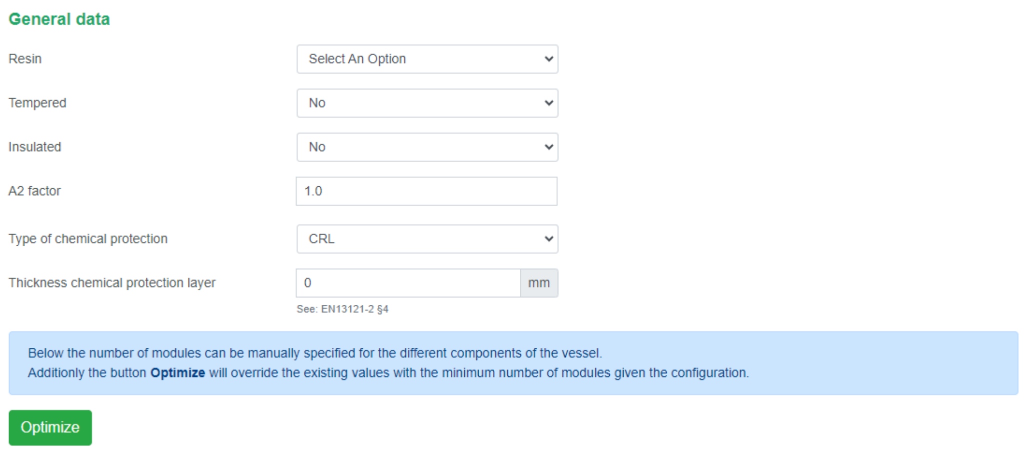
Once the loads of the tank/silo are complete, the laminates can be defined. Click on the 'Laminate thickness' header, after you confirmed your loads by clicking 'update'.

7.3.1. General

Start by entering general data, selecting the resin from your database, and indicating whether the silo is tempered/cured and insulated (yes/no impacts self-weight for structural calculations, and the calculation of the A_3-factor).

Address the A_2-factor for chemical resistance, typically set to one for dry bulk materials (silos), but depending on the type of medium for tanks storing liquids.

The type and thickness of the chemical protection barrier has to be added. Choose between a single protection layer (SPL), a chemical barrier layer (CBL) and a thermoplastic protection layer (TPL). The type and required thickness of this layer is prescribed by EN13121-2, otherwise a resin advice has to be obtained through your resin provider.



After entering all previous data, there are 2 ways to determine the required structural laminate thicknesses for your project:

1. Specify the number of modules yourself, and click 'analyse'
2. or let the Amphora algorithm determine the optimum thicknesses by clicking "optimize

! Amphora only calculates the structural thicknesses. All thicknesses visible in tables, determined by Amphora's optimisation routine, or entered manually are structural thicknesses, EXCLUDING the required thickness for the chemical protection layer.

7.3.2. Cover

The cover has two sections: the crown and the knuckle. Input the number of modules, representing the number of layers you construct. Thickness is automatically calculated based on the module thicknesses listed in your material database.

Cover

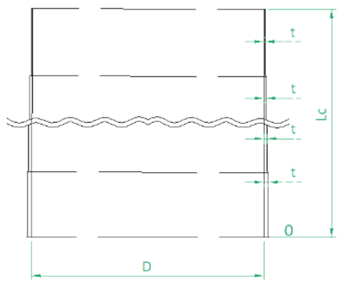
	Number of modules	Thickness	Length of reinforcement
Crown (Tb)	0	0.0 mm	
Knuckle (Tk)	0	0.0 mm	0 mm

7.3.3. Cylinder

Amphora automatically divides the cylinder into slices (or sections), the length of a slice depends on the total length of the cylinder. Adjust the number of laminate modules in each section to control the structural thickness.

Cylinder

	Number of modules	Thickness
2 → 3 m	0	0 mm
1 → 2 m	0	0 mm
0 → 1 m	0	0 mm

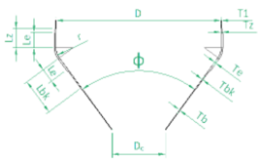


7.3.4. Bottom

Start with the crown thickness and input the number of modules for each hopper section, as indicated in the figure.

Bottom

	Number of modules	Thickness	Length of reinforcement
Crown (Tb)	0	0.0 mm	0 mm
Knuckle (Te)	0	0.0 mm	0 mm
Cylinder (Tz)	0	0.0 mm	0 mm
Crown 2 (Tbk)	0	0.0 mm	0 mm



7.3.5. Support

Proceed to input support and anchoring for uplift, dependent on the support type chosen earlier. For the skirt, enter the number of modules for the skirt, skirt upper part, and skirt lower part. Anchoring for uplift may not be applicable for some silo's, contingent on the selected support type during geometry calculations.

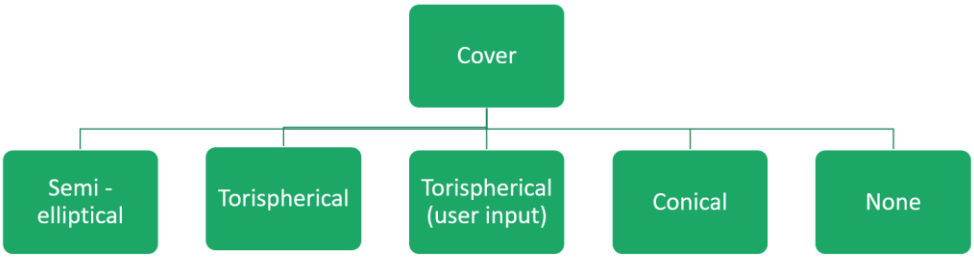
8. Rib-stiffened silo

8.1. Geometry

First, establish the geometry of the tank or silo. The process always begins at the top of the structure, working our way down, starting with the construction of the cover.

8.1.1. Cover

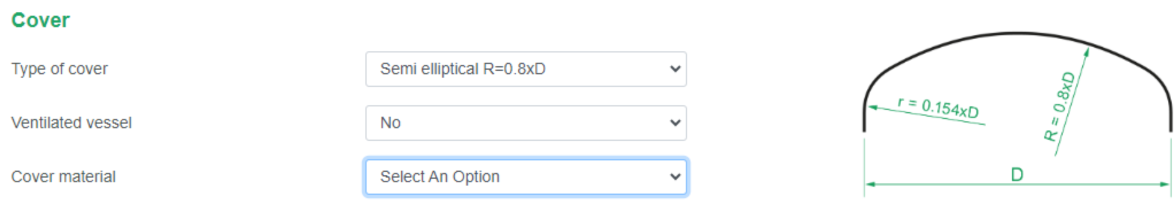
Start by selecting a cover type from the dropdown menu, which shows several geometric options, including the choice of having no cover.



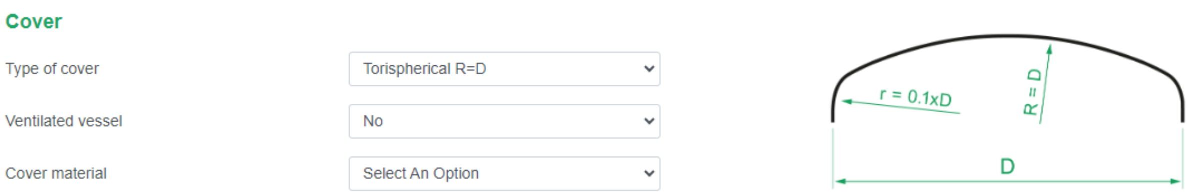
These options align with industry standards, and are presented below.

Subsequently, specify whether the vessel is ventilated. Indicate 'Yes' if there is a pipe allowing ventilation into the atmosphere or if a filter is present; otherwise, select 'No'. Finally, select the cover material. It is important to note that when adding materials, the material from which the cover is made can be specified.

8.1.1.1. Semi Elliptical Cover

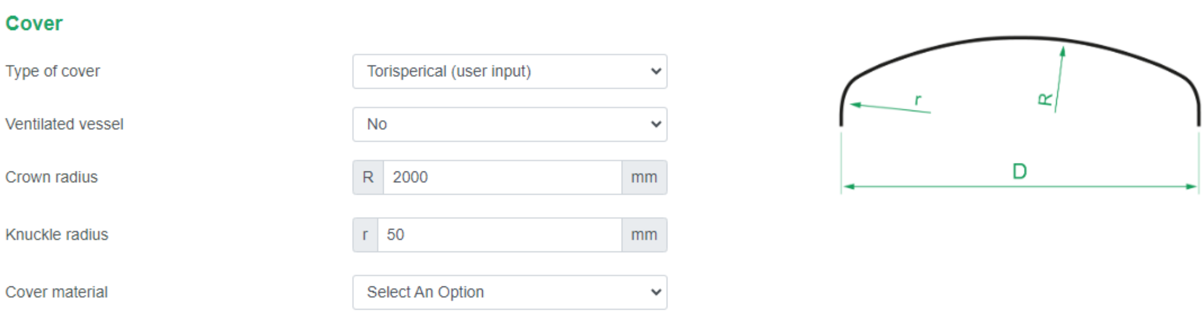


8.1.1.2. Torispherical Cover



8.1.1.3. Torispherical Cover with user input

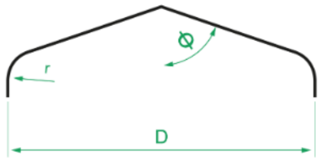
Use the ‘user input option’ for torispherical covers with deviating radii.



8.1.1.4. Conical Cover

Cover

Type of cover	Conical cover
Ventilated vessel	No
Angle	Φ 75 °
Knuckle radius	r 0 mm
Cover material	Select An Option



8.1.1.5. No Cover

Cover

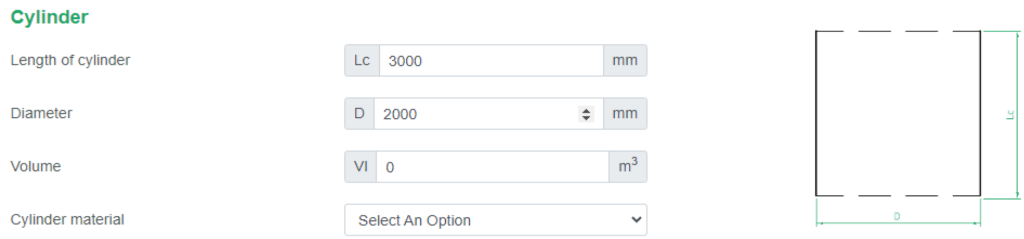
Type of cover	None
Ventilated vessel	No

The selection of ‘no cover’ automatically affects the vacuum pressure in the tank, similar to the ‘ventilated’ option.

8.1.2. Cylinder

Proceed with entering the details about the cylinder. The length and diameter have already been pre-filled based on the information you provided during the project creation phase.

At this point, the focus is only on entering the used volume and select the cylinder material.



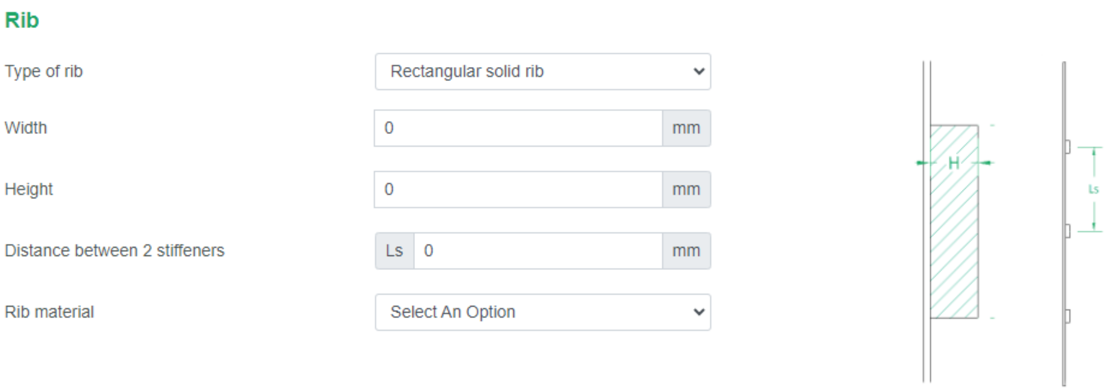
Note that Amphora automatically determines the number of sections to divide the cylinder. This is based on the 'length of cylinder'.

8.1.2.1. Ribs

The rib stiffened cylinder is stiffened by ribs.

Rectangular solid rib

The first option is the rectangular solid GFRP rib

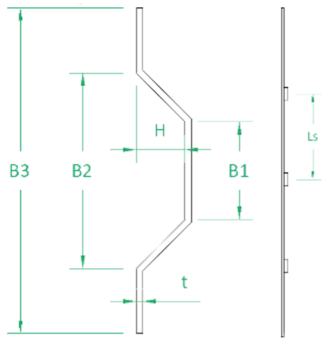


Omega stiffener

The second option is the omega GFRP rib, which can be either hollow or filled with a non-structural foam core

Rib

Type of rib	Omega stiffener		
Width top	B1	0	mm
Width bottom	B2	0	mm
Length on cylinder	B3	0	mm
Internal height	H	0	mm
Thickness	t	0	mm
Distance between 2 stiffeners	Ls	0	mm
Rib material	Select An Option		

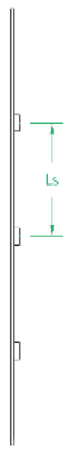


User defined rib

Select the third option when you use for example steel ribs, which are mounted to the cylinder wall

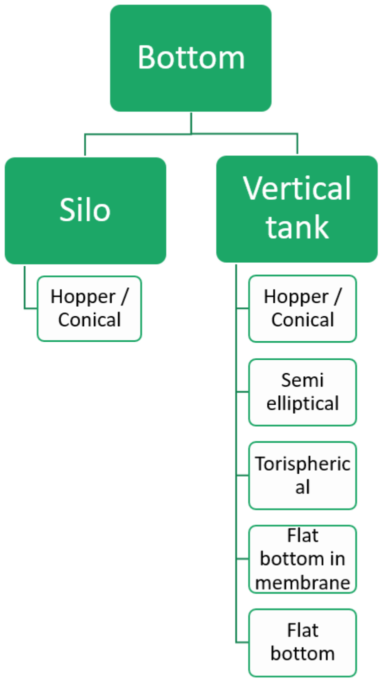
Rib

Type of rib	User defined rib		
Rib stiffness	E	0	N/mm^2
Rib moment of inertia	I	0	mm^4
Distance between 2 stiffeners	Ls	0	mm



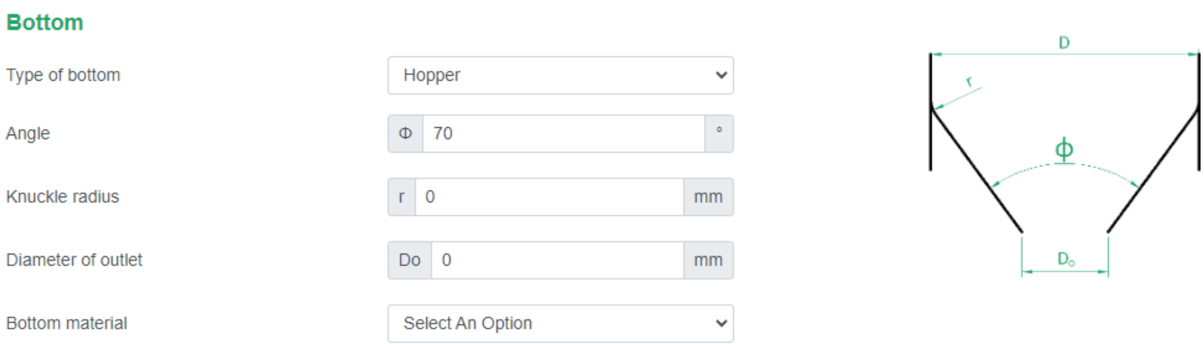
8.1.3. Bottom

In this section, provide information about the bottom of the vessel. The type of bottom can be selected, but available options depend on the type of project you are working on.



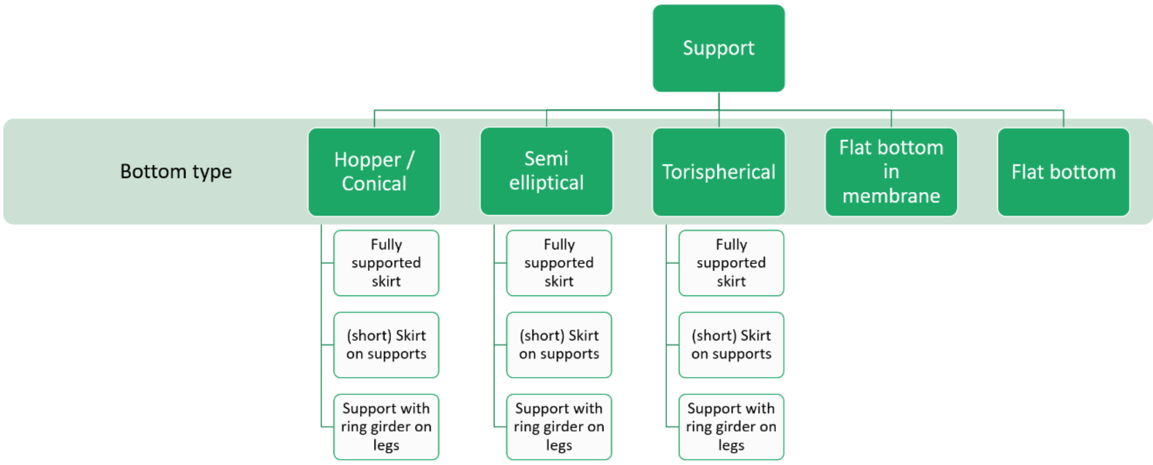
8.1.3.1. Hopper

! For silos, this is always a hopper bottom. Complete the fields for the angle of the cone, knuckle radius, diameter of the outlet, and choose the bottom material. It's important to note that hat the knuckle radius can also be zero if there is no knuckle radius.



8.1.4. Support

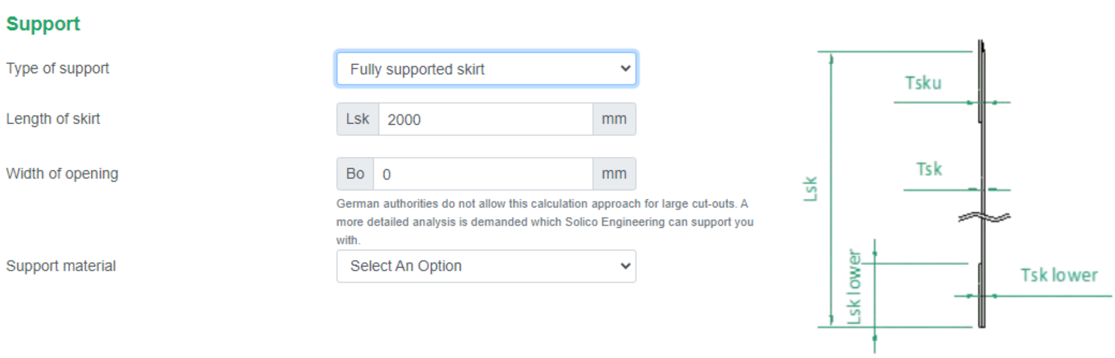
The support options change with the chosen product type and bottom type. Explore support options like skirt on supports, fully supported skirt, or support with a ring girder on legs.



Fill in details such as height, skirt length, opening width, and support material for the chosen support.

8.1.4.1. Fully supported skirt

This is a vessel on a skirt underneath the cylinder-bottom transition. This skirt is supported by the foundation over the full circumference.



When you select a fully supported skirt, an opening can be introduced. When an opening is present, enter the ‘width of the opening’, otherwise enter 0 to remove this option.

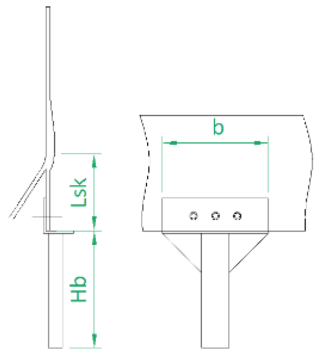
When an opening is present, you can also include the stiffness of the portal that reinforces the cut-out.

8.1.4.2. Skirt on supports

This is a vessel with a short skirt underneath the cylinder-bottom transition, supported by steel support legs or supported by a steel support structure.

Support

Type of support	Skirt on supports		
Height above ground level	hb	0	mm
Length of skirt	Lsk	300	mm
Number of supports	Ns	4	
Support width	b	300	mm
Support material	Select An Option		

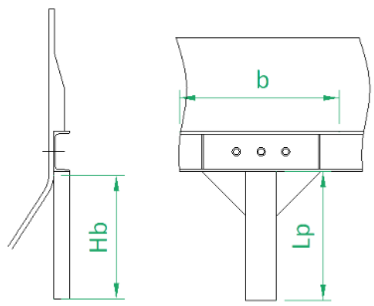


8.1.4.3. Support with ring girder on legs

This is a vessel without skirt, that has a (steel) UPN-ring bolted to the cylinder-bottom transition zone, which is in turn supported by steel support legs or supported by a steel support structure.

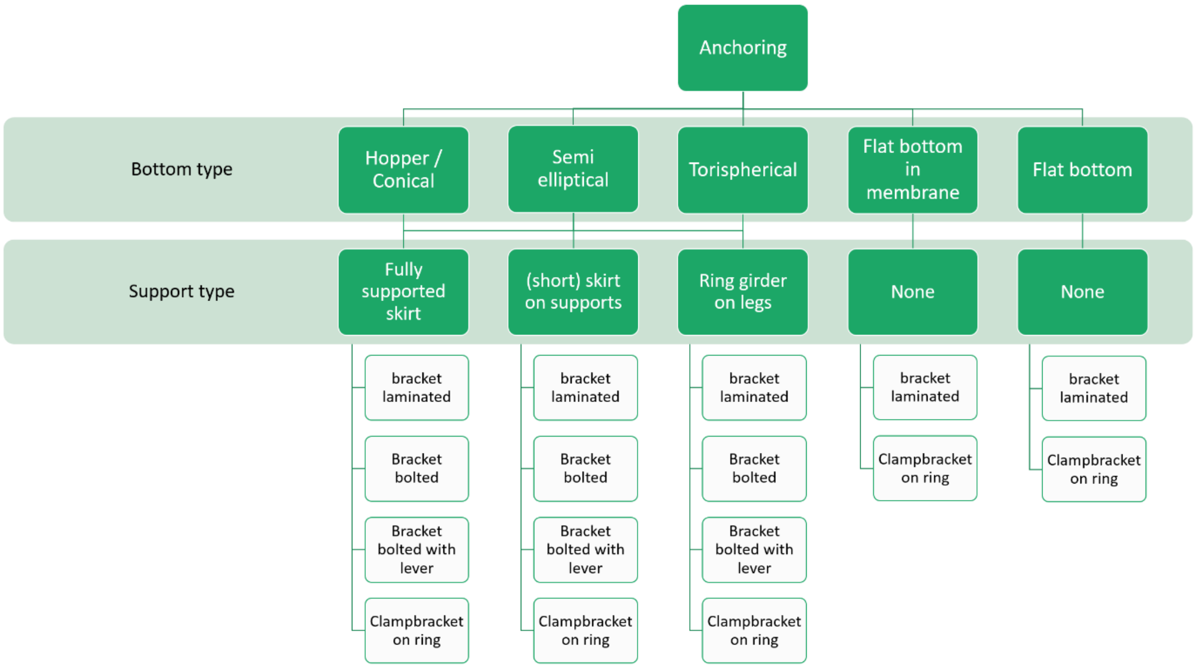
Support

Type of support	Support with ring girder on legs		
Length of legs	Lp	2000	mm
Number of legs	Np	4	
Support width per leg	b	300	mm
Support material	Select An Option		



8.1.5. Anchoring

The available anchoring options depend on the support construction. Available options are: anchoring bracket laminated, anchoring bracket bolted, clamp bracket on ring, bolted through skirt with lever, or bolted to construction.

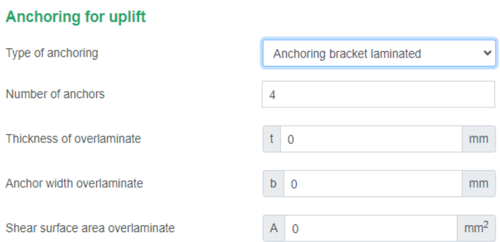


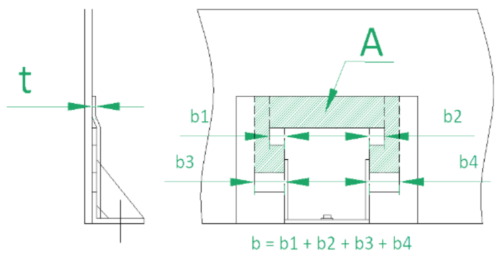
Enter the relevant information for the chosen anchoring option.

Note that the anchoring force calculated by Amphora is the vertical reaction force in the cylinder wall. The actual design force of the anchor bolt itself that connects the anchor to the vessels' foundation depends on the geometry of the used anchor bracket and has to be calculated separately.

8.1.5.1. Anchoring bracket laminated

A pre-fabricated (steel) anchor, designed such that it can be connected to the vessel with a connection laminate.



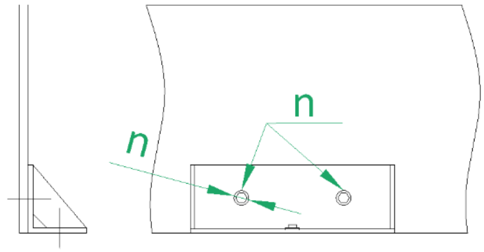


8.1.5.2. Anchoring bracket bolted

A pre-fabricated (steel) anchor, bolted to the vessel.

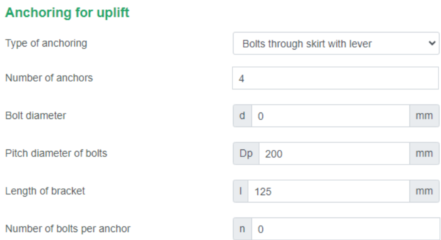

Anchoring for uplift

Type of anchoring	Anchoring bracket bolted
Number of anchors	4
Bolt diameter	d 0 mm
Number of bolts per anchor	n 0

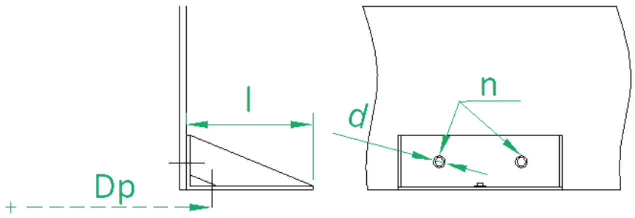


8.1.5.3. Bolts through skirt with lever

A pre-fabricated (steel) anchor with a certain eccentricity (= lever), bolted to the vessel.

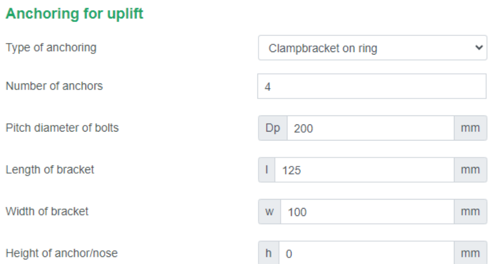

Anchoring for uplift

Type of anchoring	Bolts through skirt with lever
Number of anchors	4
Bolt diameter	d 0 mm
Pitch diameter of bolts	Dp 200 mm
Length of bracket	l 125 mm
Number of bolts per anchor	n 0

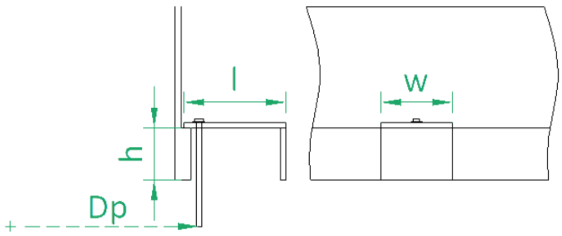


8.1.5.4. Clampbracket on ring

The lower edge of the vessel is equipped with a ‘nose’, in combination with the (steel) clampbrackets this is the anchoring of the vessel.


Anchoring for uplift

Type of anchoring	Clampbracket on ring
Number of anchors	4
Pitch diameter of bolts	Dp 200 mm
Length of bracket	l 125 mm
Width of bracket	w 100 mm
Height of anchor/nose	h 0 mm



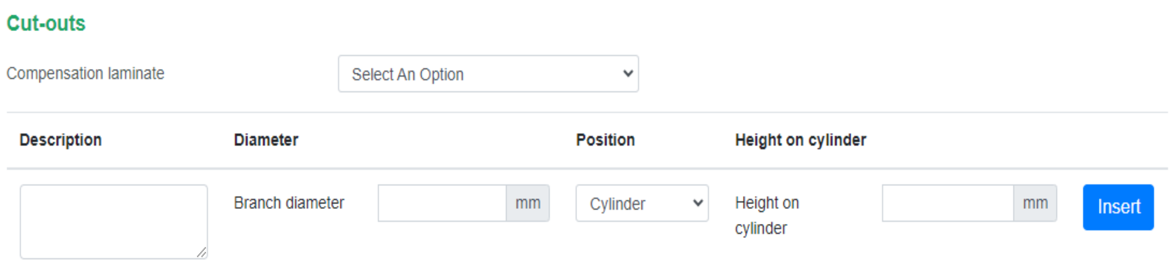
8.1.6. Cut-outs

The Cut-outs module serves to determine the thickness of the compensation laminate when incorporating cut-outs for nozzles or filter mounts into your design.

Each different cut-out can be given a name, and a diameter. The cut-outs can be placed in the cover, bottom, and the cylinder. In case the cut-out is located in the cylinder, the height of the cut-out along the cylinder has to be provided as well.

It's essential to be aware that, within this module, Amphora exclusively considers the loads present in the vessel and the hydrostatic pull-out pressure. Amphora does not factor in any external loads on the nozzle.

> ! Amphora does not take into account any external nozzle loads.



SOLICO
PROJECTS IN COMPOSITES

8.2. Loads

Once the geometry of the tank/silo is complete, the loads can start being defined. Once the geometry is completed, click on the 'Loads' header, after you confirmed your geometry by clicking 'update'.

8.2.1. Load from content

Begin by specifying the medium type and its dedicated density. Dry bulk mediums require unique pressure and wall friction coefficients. The default values in Amphora are the conservative values according to the EN1991-4. Other values can be entered, based on testing values or the EN 1991-4 standard.

Input the bottom load magnifying factor and refer to "more info" if needed.

Finally, enter the design temperature.

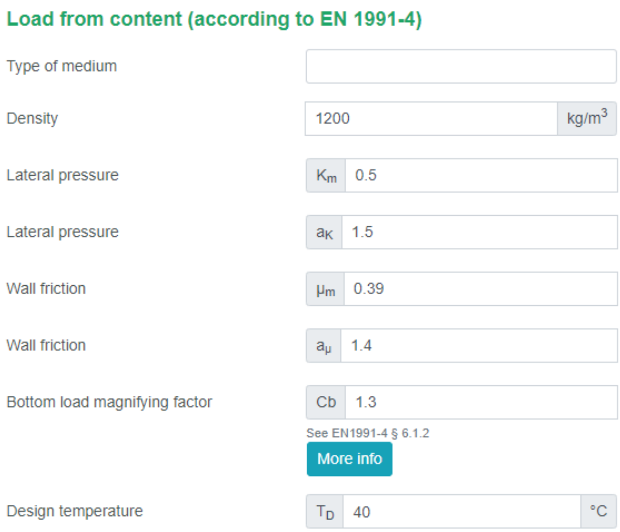


Table E.1: Particulate solids properties

Type of particulate solid [d, e]	Unit weight [b] γ		Angle of repose ϕ_r	Angle of internal friction ϕ_i		Lateral pressure ratio K		Wall friction coefficient [c] μ ($\mu = \tan \phi_w$)				Patch load solid reference factor C_{op}
	γ_l	γ_u	ϕ_r	ϕ_{im}	a_ϕ	K_m	a_K	Wall type D1	Wall type D2	Wall type D3	a_μ	
	Lower	Upper		Mean	Factor	Mean	Factor	Mean	Mean	Mean	Factor	
	kN/m³	kN/m³	degrees	degrees								
Default material [a]	6,0	22,0	40	35	1,3	0,50	1,5	0,32	0,39	0,50	1,40	1,0
Aggregate	17,0	18,0	36	31	1,16	0,52	1,15	0,39	0,49	0,59	1,12	0,4
Alumina	10,0	12,0	36	30	1,22	0,54	1,20	0,41	0,46	0,51	1,07	0,5
Animal feed mix	5,0	6,0	39	36	1,08	0,45	1,10	0,22	0,30	0,43	1,28	1,0
Animal feed pellets	6,5	8,0	37	35	1,06	0,47	1,07	0,23	0,28	0,37	1,20	0,7
Barley ○	7,0	8,0	31	28	1,14	0,59	1,11	0,24	0,33	0,48	1,16	0,5
Cement	13,0	16,0	36	30	1,22	0,54	1,20	0,41	0,46	0,51	1,07	0,5
Cement clinker ‡	15,0	18,0	47	40	1,20	0,38	1,31	0,46	0,56	0,62	1,07	0,7
Coal ○	7,0	10,0	36	31	1,16	0,52	1,15	0,44	0,49	0,59	1,12	0,6
Coal, powdered ○	6,0	8,0	34	27	1,26	0,58	1,20	0,41	0,51	0,56	1,07	0,5
Coke	6,5	8,0	36	31	1,16	0,52	1,15	0,49	0,54	0,59	1,12	0,6
Flyash	8,0	15,0	41	35	1,16	0,46	1,20	0,51	0,62	0,72	1,07	0,5
Flour ○	6,5	7,0	45	42	1,06	0,36	1,11	0,24	0,33	0,48	1,16	0,6
Iron ore pellets	19,0	22,0	36	31	1,16	0,52	1,15	0,49	0,54	0,59	1,12	0,5
Lime, hydrated	6,0	8,0	34	27	1,26	0,58	1,20	0,36	0,41	0,51	1,07	0,6
Limestone powder	11,0	13,0	36	30	1,22	0,54	1,20	0,41	0,51	0,56	1,07	0,5
Maize ○	7,0	8,0	35	31	1,14	0,53	1,14	0,22	0,36	0,53	1,24	0,9
Phosphate	16,0	22,0	34	29	1,18	0,56	1,15	0,39	0,49	0,54	1,12	0,5
Potatoes	6,0	8,0	34	30	1,12	0,54	1,11	0,33	0,38	0,48	1,16	0,5
Sand	14,0	16,0	39	36	1,09	0,45	1,11	0,38	0,48	0,57	1,16	0,4
Slag clinkers	10,5	12,0	39	36	1,09	0,45	1,11	0,48	0,57	0,67	1,16	0,6
Soya beans	7,0	8,0	29	25	1,16	0,63	1,11	0,24	0,38	0,48	1,16	0,5
Sugar ○	8,0	9,5	38	32	1,19	0,50	1,20	0,46	0,51	0,56	1,07	0,4
Sugarbeet pellets	6,5	7,0	36	31	1,16	0,52	1,15	0,35	0,44	0,54	1,12	0,5
Wheat ○	7,5	9,0	34	30	1,12	0,54	1,11	0,24	0,38	0,57	1,16	0,5

NOTE Where this table does not contain the material to be stored, testing should be undertaken.

[a] For situations where it is difficult to justify the cost of testing, because the cost implications of using a wide property range for the design are minor, the properties of the "default material" may be used. For small installations, these properties may be adequate. However, they will lead to very uneconomic designs for large silos, and testing should always be preferred.

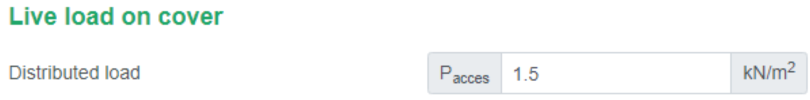
[b] The unit weight of the solid γ_u is the upper characteristic value, to be used for all calculations of actions. The lower characteristic value γ_l is provided in Table E.1 to assist in estimating the required volume of a silo that will have a defined capacity.

[c] Effective wall friction for wall Type D4 (corrugated wall) may be found using the method defined in Annex D, D.2.

[d] Solids in this table that are known to be susceptible to dust explosion are identified by the symbol ○

[e] Solids that are susceptible to mechanical interlocking are identified by the symbol ‡

8.2.2. Pressure



Enter the design pressure and design vacuum. Indicate whether it is a short term or long term load using the dropdown menu. For additional details, click on "more info". If no pressures are provided, the EN-standard obliges to consider a minimum internal and external pressure, what Amphora does automatically.

Consider charging and discharging by filling in zero to automatically adhere to standards. For silos with features like an explosion hatch, enter the maximum reduced explosion pressure as needed.

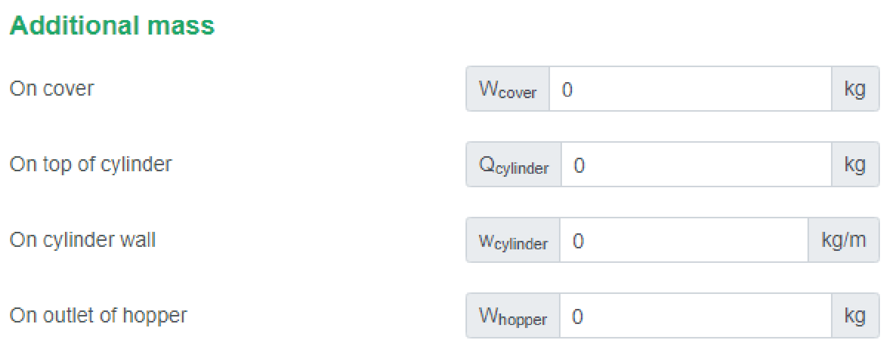
! Amphora will always consider the minimum pressures prescribed by the standard, even when the pressures are set to zero by the user.

8.2.3. Live load

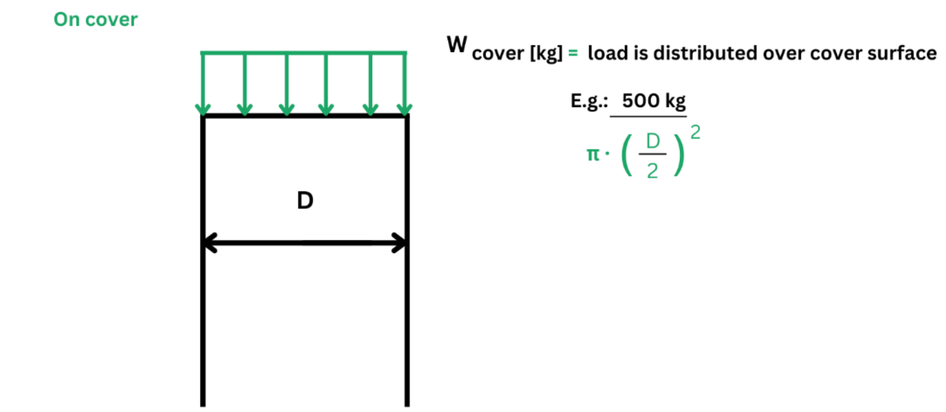
Just like for the pressures, the standard describes the minimum value which is always considered. If nothing is filled in, the minimum value described in the standard is applied.

8.2.4. Additional mass

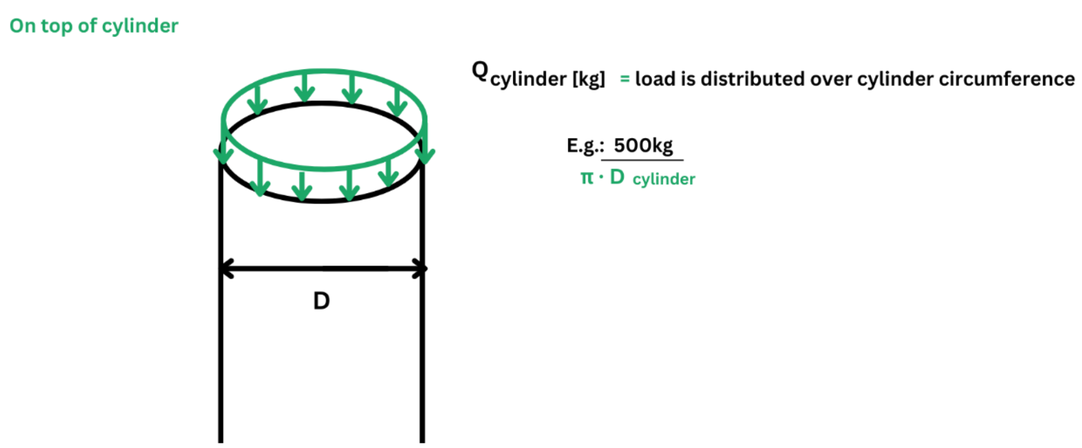
There is a possibility to add additional masses, depending on the location. Additional masses can be located on the cover, cylinder, hand railing, ladder or hopper outlet.



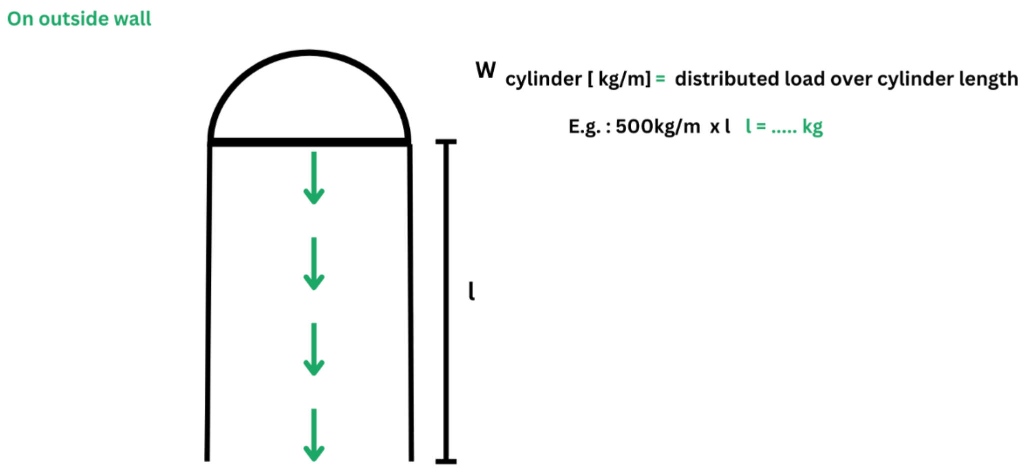
8.2.4.1. Additional Mass on cover



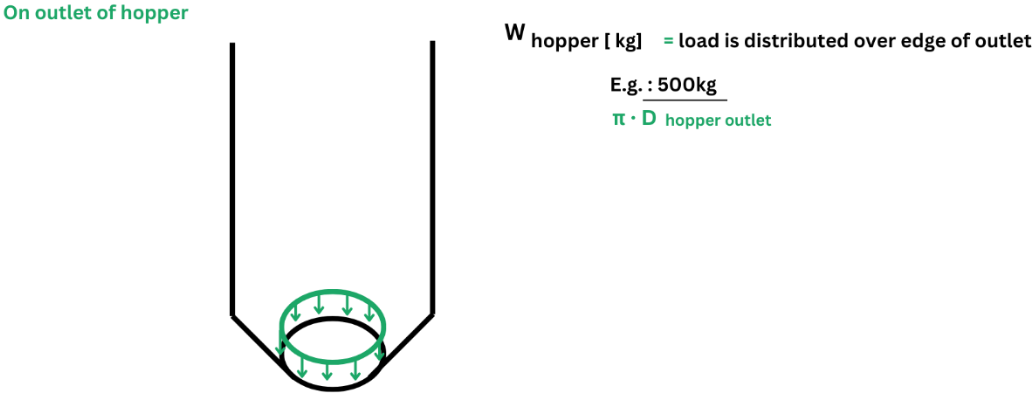
8.2.4.2. Additional Mass on top of cylinder



8.2.4.3. Additional Mass on outside wall



8.2.4.4. Additional Mass on outlet of hopper



8.2.5. Wind and snow

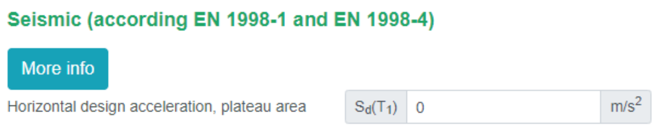
Currently Amphora can automatically determine the wind and snow load for the Benelux, Germany, France and Italy. These loads are compliant with the national annexes of the EN1991-1-3 and EN1991-1-4 of each respective country.
To use this functionality a country, a wind zone, a terrain category and a snow zone has to be selected from the pull-down menu, based on the delivery location of your vessel.

If your vessel is located outside the available countries in Amphora, you can select the option “user input” from the “country” pull-down menu. This allows you to fill in the values of the extreme wind pressure and snow load on the ground for the location. These pressures can be calculated according to the national annex of the EN1991-1-3 and EN1991-1-4 of the specific country.

8.2.6. Seismic Loads

Depending on the location of your vessel, the seismic loads in accordance with the EN 1998 standard can be entered.

You need to calculate/enter the horizontal design acceleration in the plateau area of the response spectrum. Based on the location, the locations soil type and the importance class of your vessel. This is a conservative approach.



If you know the eigenfrequency of your system, a different value can be entered, based on your calculations.

This is a complex calculation that hinges on various factors. For additional assistance, click on "more info.", or contact the amphora admin if Solico’s assistance is required.

8.3. Laminate thickness

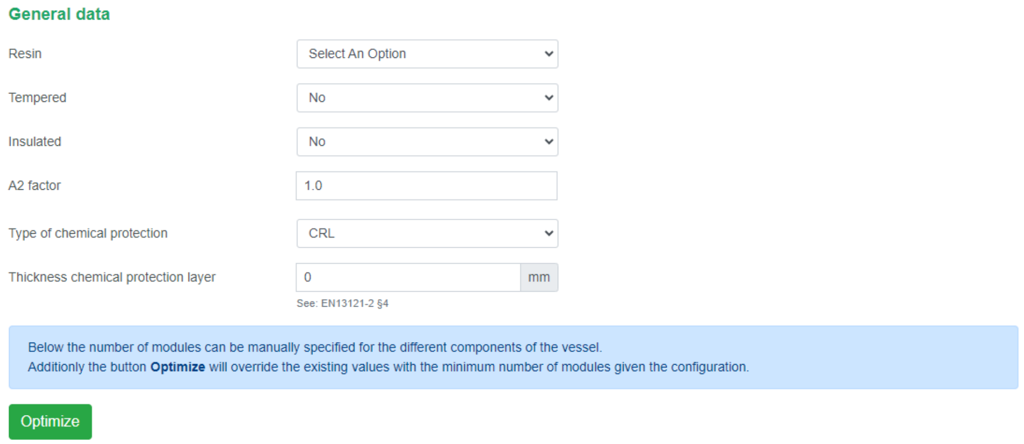
Once the loads of the tank/silo are complete, the laminates can be defined. Click on the 'Laminate thickness' header, after you confirmed your loads by clicking 'update'.

8.3.1. General

Start by entering general data, selecting the resin from your database, and indicating whether the silo is tempered/cured and insulated (yes/no impacts self-weight for structural calculations, and the calculation of the A_3-factor).

Address the A_2-factor for chemical resistance, typically set to one for dry bulk materials (silos), but depending on the type of medium for tanks storing liquids.

The type and thickness of the chemical protection barrier has to be added. Choose between a single protection layer (SPL), a chemical barrier layer (CBL) and a thermoplastic protection layer (TPL). The type and required thickness of this layer is prescribed by EN13121-2, otherwise a resin advice has to be obtained through your resin provider.



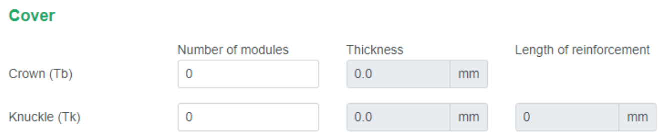
After entering all previous data, there are 2 ways to determine the required structural laminate thicknesses for your project:

1. Specify the number of modules yourself, and click 'analyse'
2. or let the Amphora algorithm determine the optimum thicknesses by clicking "optimize

! Amphora only calculates the structural thicknesses. All thicknesses visible in tables, determined by Amphora's optimisation routine, or entered manually are structural thicknesses, EXCLUDING the required thickness for the chemical protection layer.

8.3.2. Cover

The cover has two sections: the crown and the knuckle. Input the number of modules, representing the number of layers you construct. Thickness is automatically calculated based on the module thicknesses listed in your material database.

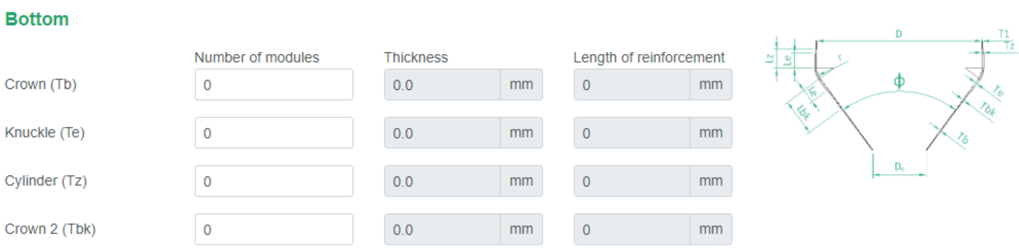


8.3.3. Cylinder

Amphora automatically divides the cylinder into slices (or sections), the length of a slice depends on the total length of the cylinder. Adjust the number of laminate modules in each section to control the structural thickness.

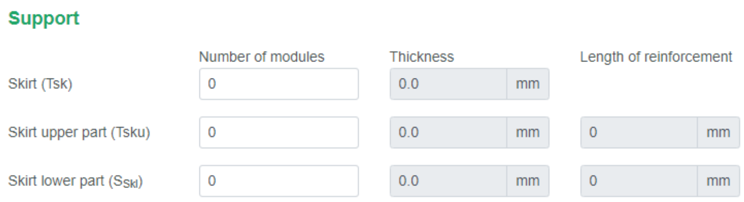
8.3.4. Bottom

Start with the crown thickness and input the number of modules for each hopper section, as indicated in the figure.



8.3.5. Support

Proceed to input support and anchoring for uplift, dependent on the support type chosen earlier. For the skirt, enter the number of modules for the skirt, skirt upper part, and skirt lower part. Anchoring for uplift may not be applicable for some silo’s, contingent on the selected support type during geometry calculations.



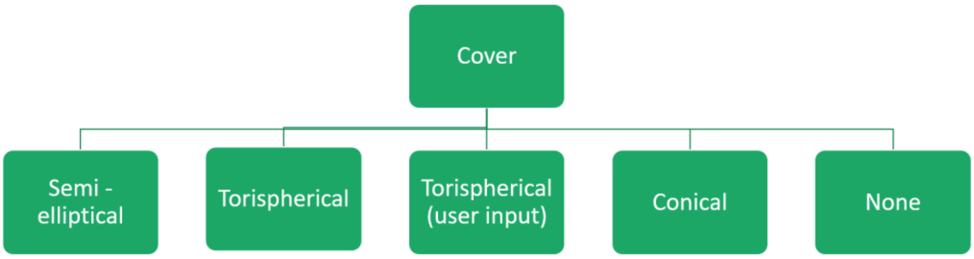
9. Rib-Stiffened Vertical Tank

9.1. Geometry

First, establish the geometry of the tank or silo. The process always begins at the top of the structure, working our way down, starting with the construction of the cover.

9.1.1. Cover

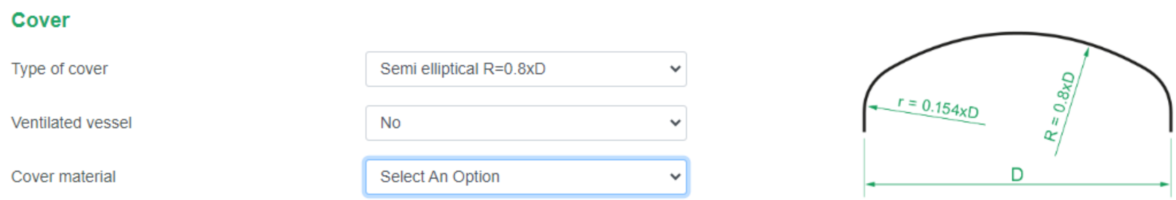
Start by selecting a cover type from the dropdown menu, which shows several geometric options, including the choice of having no cover.



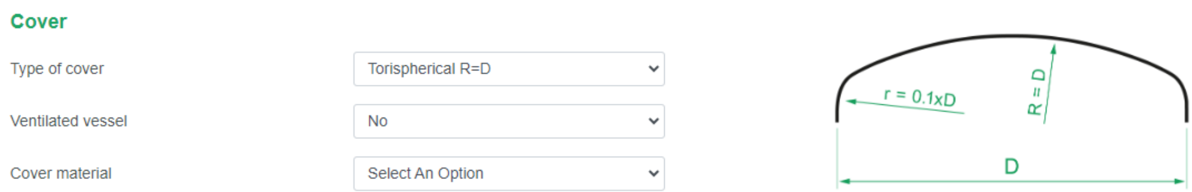
These options align with industry standards, and are presented below.

Subsequently, specify whether the vessel is ventilated. Indicate 'Yes' if there is a pipe allowing ventilation into the atmosphere or if a filter is present; otherwise, select 'No'. Finally, select the cover material. It is important to note that when adding materials, the material from which the cover is made can be specified.

9.1.1.1. Semi Elliptical Cover

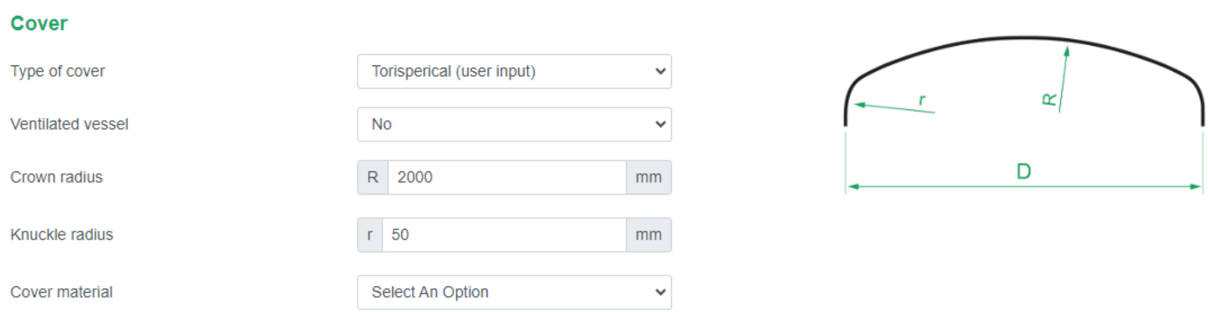


9.1.1.2. Torispherical Cover

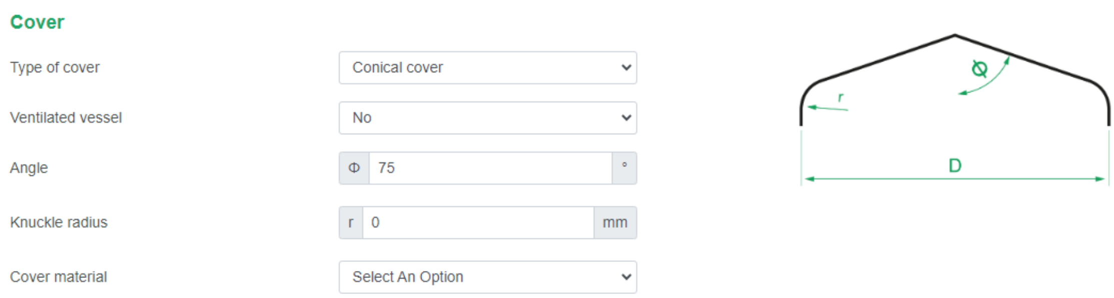


9.1.1.3. Torispherical Cover with user input

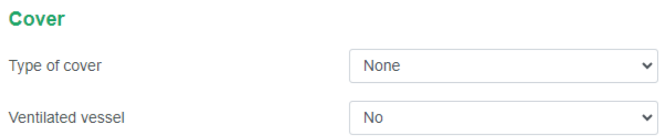
Use the ‘user input option’ for torispherical covers with deviating radii.



9.1.1.4. Conical Cover



9.1.1.5. No Cover

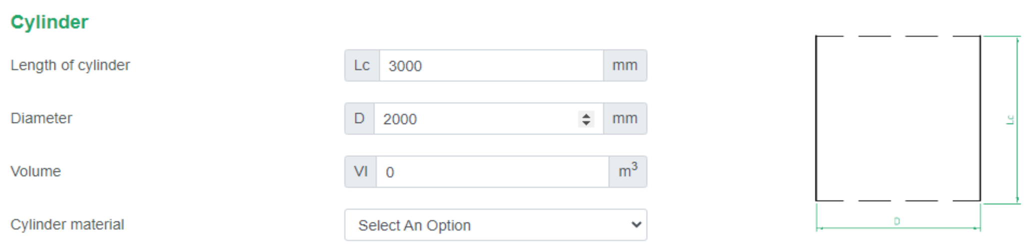


The selection of ‘no cover’ automatically affects the vacuum pressure in the tank, similar to the ‘ventilated’ option.

9.1.2. Cylinder

Proceed with entering the details about the cylinder. The length and diameter have already been pre-filled based on the information you provided during the project creation phase.

At this point, the focus is only on entering the used volume and select the cylinder material.



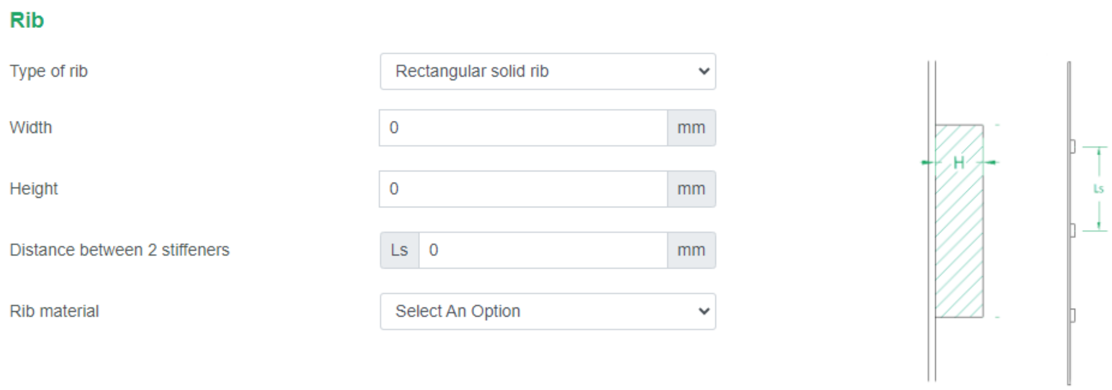
Note that Amphora automatically determines the number of sections to divide the cylinder. This is based on the 'length of cylinder'.

9.1.2.1. Ribs

The rib stiffened cylinder is stiffened by ribs.

Rectangular solid rib

The first option is the rectangular solid GFRP rib

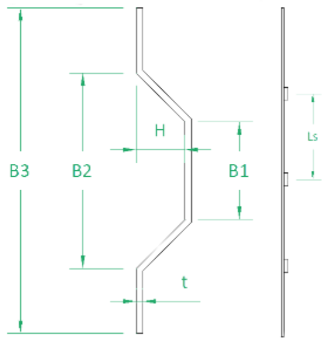


Omega stiffener

The second option is the omega GFRP rib, which can be either hollow or filled with a non-structural foam core

Rib

Type of rib	Omega stiffener		
Width top	B1	0	mm
Width bottom	B2	0	mm
Length on cylinder	B3	0	mm
Internal height	H	0	mm
Thickness	t	0	mm
Distance between 2 stiffeners	Ls	0	mm
Rib material	Select An Option		

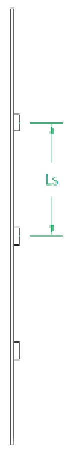


User defined rib

Select the third option when you use for example steel ribs, which are mounted to the cylinder wall

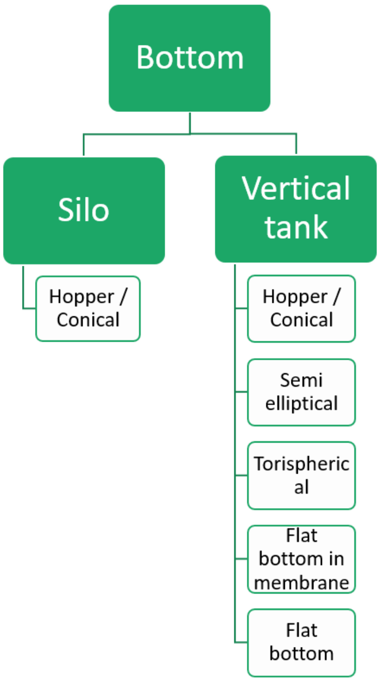
Rib

Type of rib	User defined rib		
Rib stiffness	E	0	N/mm^2
Rib moment of inertia	I	0	mm^4
Distance between 2 stiffeners	Ls	0	mm



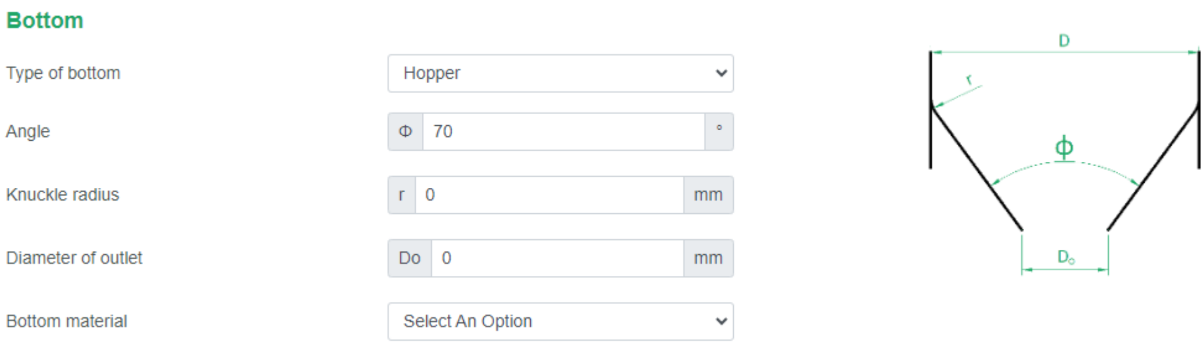
9.1.3. Bottom

In this section, provide information about the bottom of the vessel. The type of bottom can be selected, but available options depend on the type of project you are working on.



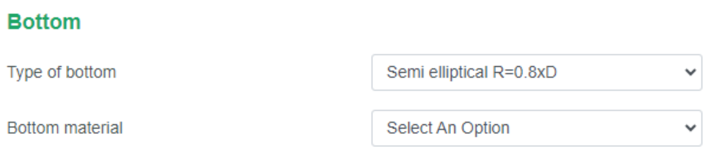
9.1.3.1. Hopper

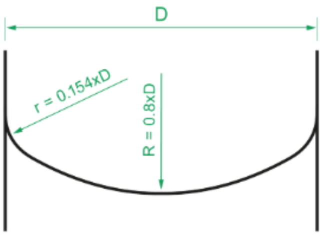
Complete the fields for the angle of the cone, knuckle radius, diameter of the outlet, and choose the bottom material. It's important to note that hat the knuckle radius can also be zero if there is no knuckle radius.



9.1.3.2. Semi elliptical bottom

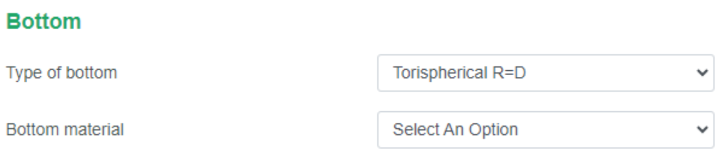
Choose the bottom material.

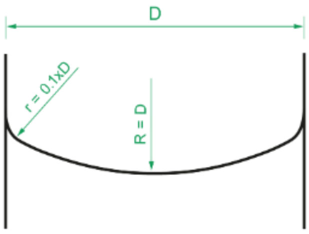




9.1.3.3. Torishpherical bottom

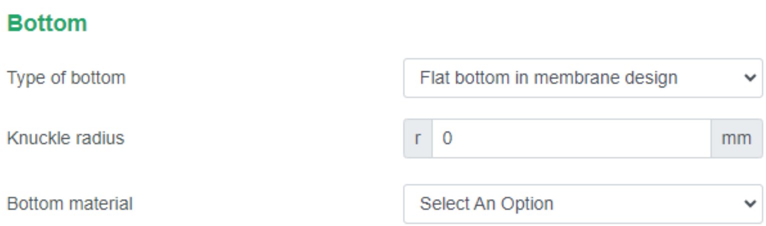
Choose the bottom material.

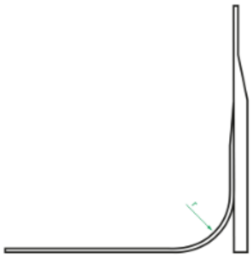




9.1.3.4. Flat bottom in membrane design

Complete the fields for the radius of the knuckle and choose the bottom material.



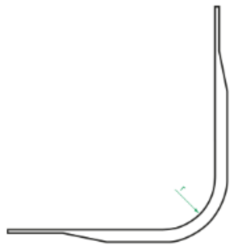


9.1.3.5. Flat bottom with knuckle

Complete the fields for the radius of the knuckle and choose the bottom material.

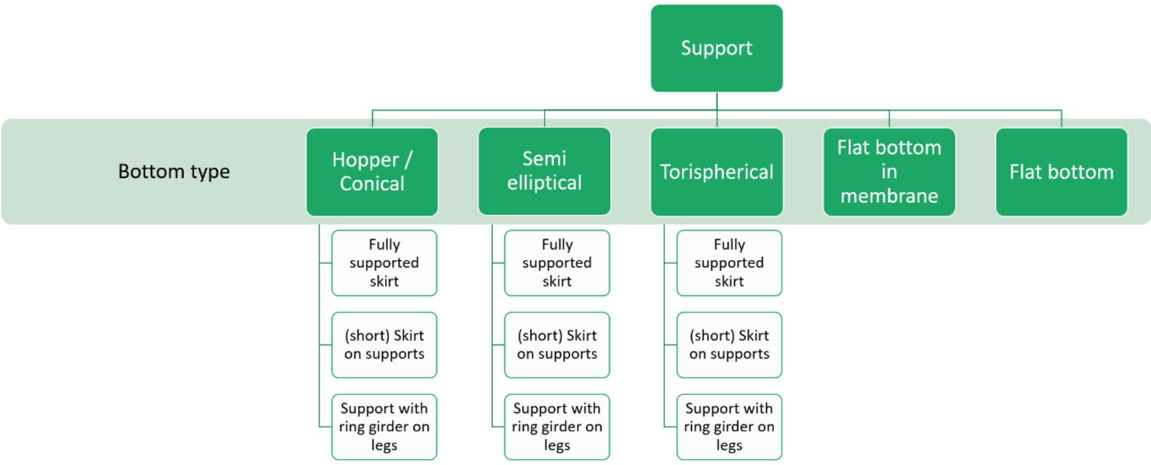
Bottom

Type of bottom	Flat bottom with knuckle
Knuckle radius	r 0 mm
Bottom material	Select An Option



9.1.4. Support

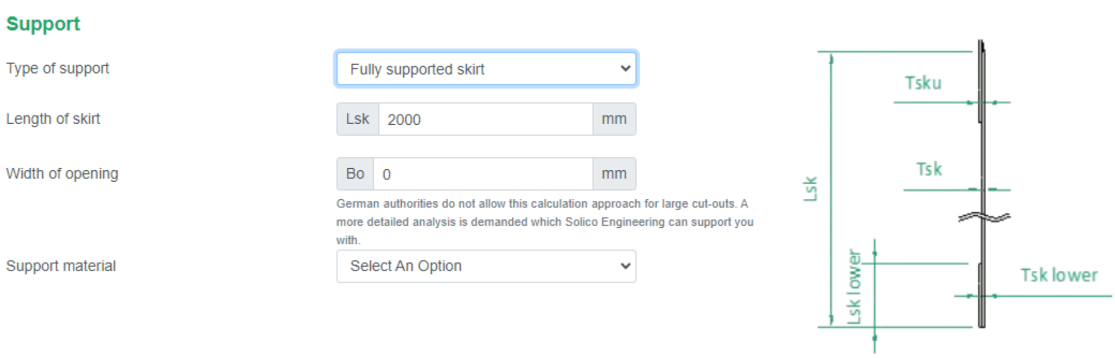
The support options change with the chosen product type and bottom type. Explore support options like skirt on supports, fully supported skirt, or support with a ring girder on legs.



Fill in details such as height, skirt length, opening width, and support material for the chosen support.

9.1.4.1. Fully supported skirt

This is a vessel on a skirt underneath the cylinder-bottom transition. This skirt is supported by the foundation over the full circumference.



When you select a fully supported skirt, an opening can be introduced. When an opening is present, enter the 'width of the opening', otherwise enter 0 to remove this option.

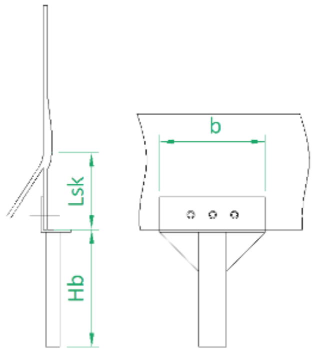
When an opening is present, you can also include the stiffness of the portal that reinforces the cut-out.

9.1.4.2. Skirt on supports

This is a vessel with a short skirt underneath the cylinder-bottom transition, supported by steel support legs or supported by a steel support structure.

Support

Type of support	Skirt on supports		
Height above ground level	hb	0	mm
Length of skirt	Lsk	300	mm
Number of supports	Ns	4	
Support width	b	300	mm
Support material	Select An Option		

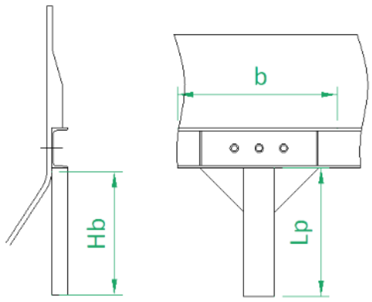


9.1.4.3. Support with ring girder on legs

This is a vessel without skirt, that has a (steel) UPN-ring bolted to the cylinder-bottom transition zone, which is in turn supported by steel support legs or supported by a steel support structure.

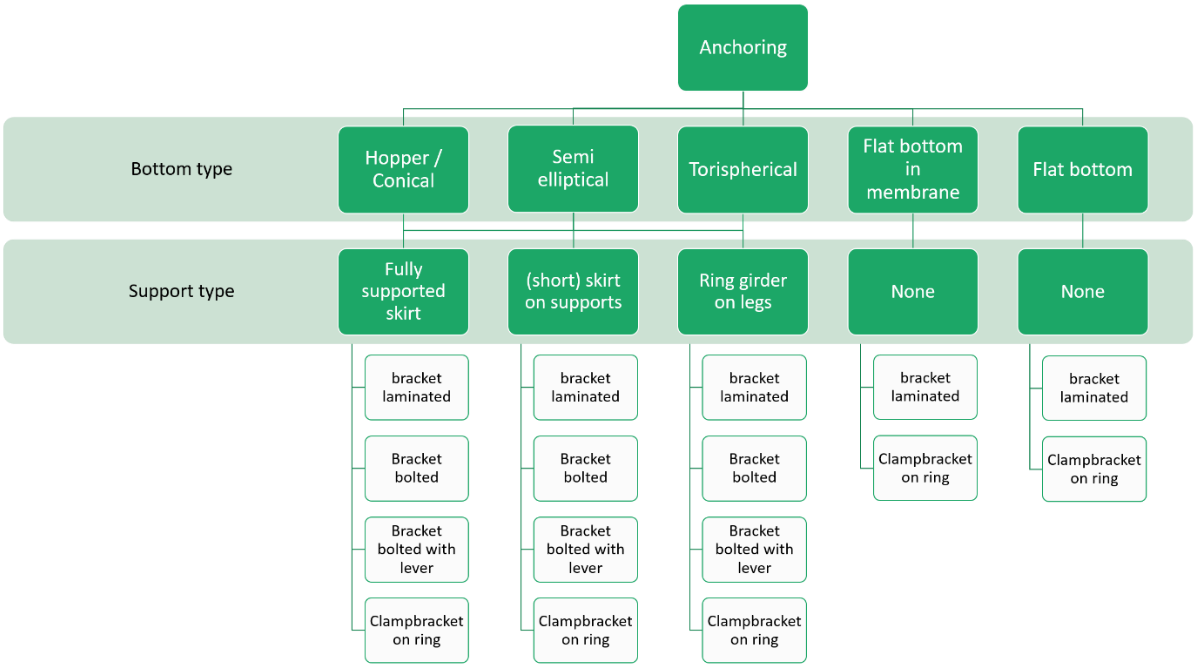
Support

Type of support	Support with ring girder on legs		
Length of legs	Lp	2000	mm
Number of legs	Np	4	
Support width per leg	b	300	mm
Support material	Select An Option		



9.1.5. Anchoring

The available anchoring options depend on the support construction. Available options are: anchoring bracket laminated, anchoring bracket bolted, clamp bracket on ring, bolted through skirt with lever, or bolted to construction.

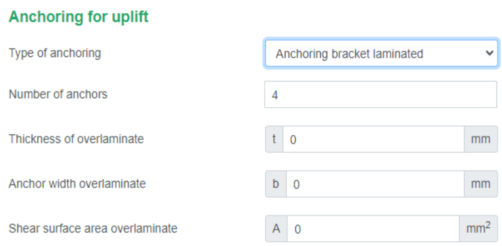


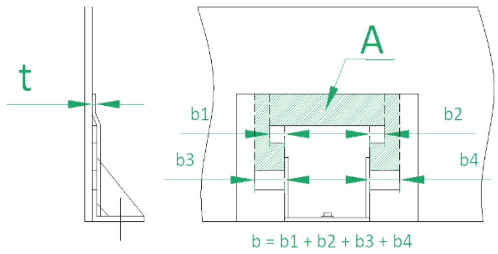
Enter the relevant information for the chosen anchoring option.

Note that the anchoring force calculated by Amphora is the vertical reaction force in the cylinder wall. The actual design force of the anchor bolt itself that connects the anchor to the vessels' foundation depends on the geometry of the used anchor bracket and has to be calculated separately.

9.1.5.1. Anchoring bracket laminated

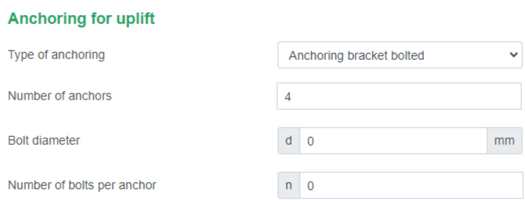
A pre-fabricated (steel) anchor, designed such that it can be connected to the vessel with a connection laminate.

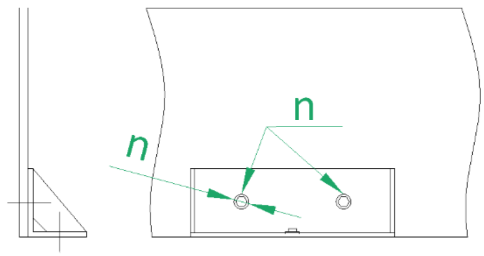




9.1.5.2. Anchoring bracket bolted

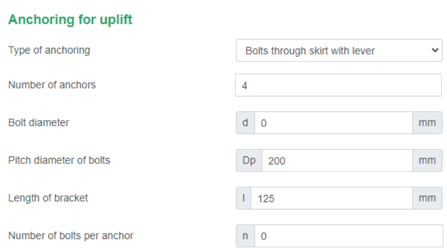
A pre-fabricated (steel) anchor, bolted to the vessel.

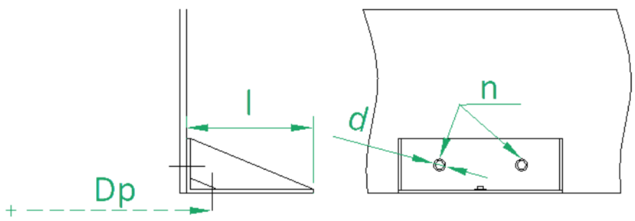




9.1.5.3. Bolts through skirt with lever

A pre-fabricated (steel) anchor with a certain eccentricity (= lever), bolted to the vessel.



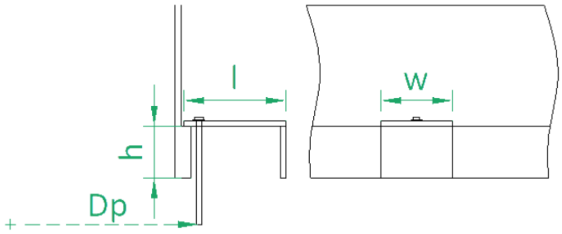


9.1.5.4. Clampbracket on ring

The lower edge of the vessel is equipped with a ‘nose’, in combination with the (steel) clampbrackets this is the anchoring of the vessel.

Anchoring for uplift

Type of anchoring		Clampbracket on ring	
Number of anchors		4	
Pitch diameter of bolts	Dp	200	mm
Length of bracket	l	125	mm
Width of bracket	w	100	mm
Height of anchor/nose	h	0	mm



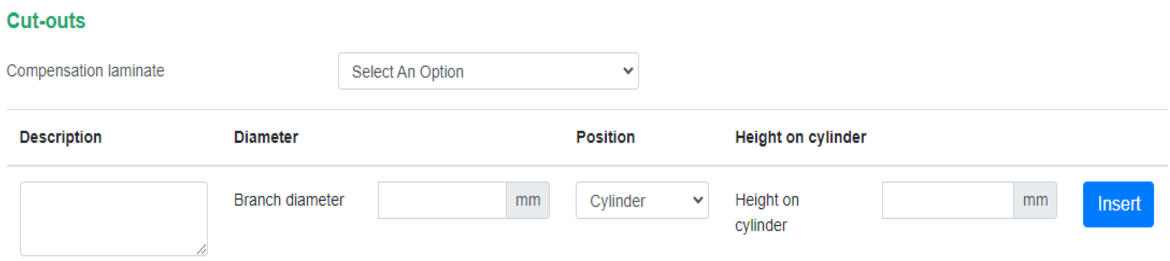
9.1.6. Cut-outs

The Cut-outs module serves to determine the thickness of the compensation laminate when incorporating cut-outs for nozzles or filter mounts into your design.

Each different cut-out can be given a name, and a diameter. The cut-outs can be placed in the cover, bottom, and the cylinder. In case the cut-out is located in the cylinder, the height of the cut-out along the cylinder has to be provided as well.

It's essential to be aware that, within this module, Amphora exclusively considers the loads present in the vessel and the hydrostatic pull-out pressure. Amphora does not factor in any external loads on the nozzle.

> ! Amphora does not take into account any external nozzle loads.



9.2. Loads

Once the geometry of the tank/silo is complete, the loads can start being defined. Once the geometry is completed, click on the ‘Loads’ header, after you confirmed your geometry by clicking ‘update’.

9.2.1. Load from content

Begin by specifying the medium type, its density, and the design temperature

9.2.2. Pressure

Enter the design pressure and design vacuum. Indicate whether it is a short term or long term load using the dropdown menu. For additional details, click on "more info". If no pressures are provided, the EN-standard obliges to consider a minimum internal and external pressure, what Amphora does automatically.

Consider charging and discharging by filling in zero to automatically adhere to standards. For silos with features like an explosion hatch, enter the maximum reduced explosion pressure as needed.

! Amphora will always consider the minimum pressures prescribed by the standard, even when the pressures are set to zero by the user.

9.2.3. Live load

Live load on cover

Distributed load	P_{acces}	1.5	kN/m^2

Just like for the pressures, the standard describes the minimum value which is always considered. If nothing is filled in, the minimum value described in the standard is applied.

9.2.4. Additional mass

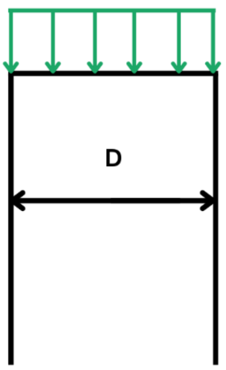
There is a possibility to add additional masses, depending on the location. Additional masses can be located on the cover, cylinder, hand railing, ladder or hopper outlet.

Additional mass

On cover	W_{cover}	0	kg
On top of cylinder	$Q_{cylinder}$	0	kg
On cylinder wall	$W_{cylinder}$	0	kg/m
On outlet of hopper	W_{hopper}	0	kg

9.2.4.1. Additional Mass on cover

On cover

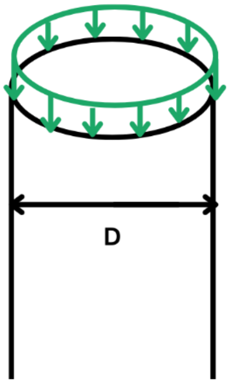


$W_{cover\,[kg]}$ = load is distributed over cover surface

E.g.: $\dfrac{500\ kg}{\pi \cdot \left(\frac{D}{2}\right)^2}$

9.2.4.2. Additional Mass on top of cylinder

On top of cylinder

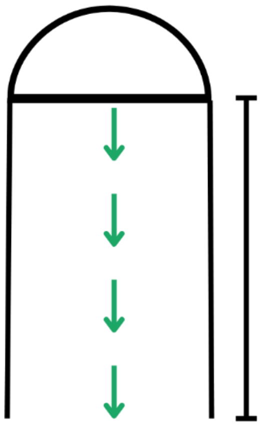


$Q_{cylinder\ [kg]}$ = load is distributed over cylinder circumference

E.g.: $\frac{500kg}{\pi \cdot D_{cylinder}}$

9.2.4.3. Additional Mass on outside wall

On outside wall

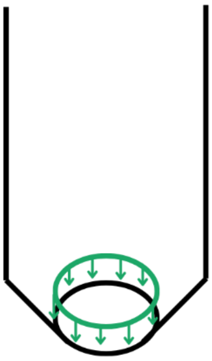


$W_{cylinder\ [kg/m]}$ = distributed load over cylinder length

E.g. : 500kg/m x l l = ... kg

9.2.4.4. Additional Mass on outlet of hopper

On outlet of hopper

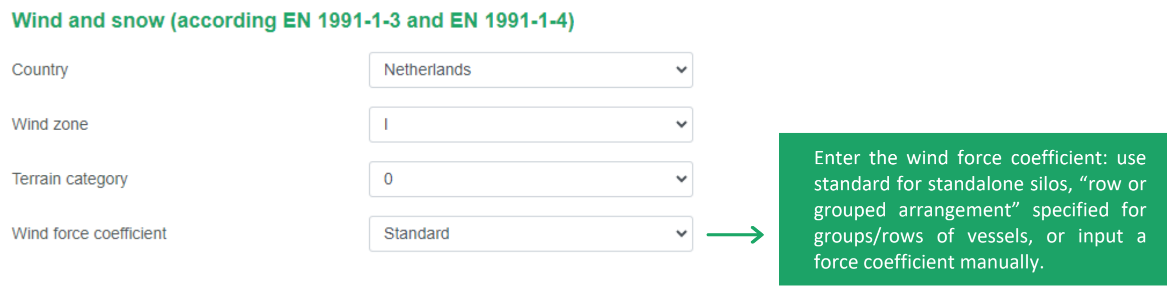


$W_{hopper\ [kg]}$ = load is distributed over edge of outlet

E.g. : $\frac{500kg}{\pi \cdot D_{hopper\ outlet}}$

9.2.5. Wind and snow

Currently Amphora can automatically determine the wind and snow load for the Benelux, Germany, France and Italy. These loads are compliant with the national annexes of the EN1991-1-3 and EN1991-1-4 of each respective country.
To use this functionality a country, a wind zone, a terrain category and a snow zone has to be selected from the pull-down menu, based on the delivery location of your vessel.



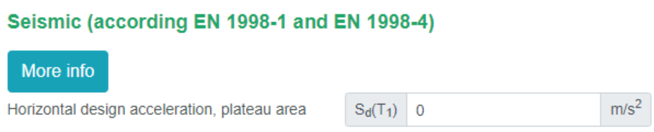
If your vessel is located outside the available countries in Amphora, you can select the option “user input” from the “country” pull-down menu. This allows you to fill in the values of the extreme wind pressure and snow load on the ground for the location. These pressures can be calculated according to the national annex of the EN1991-1-3 and EN1991-1-4 of the specific country.

9.2.6. Seismic Loads

Depending on the location of your vessel, the seismic loads in accordance with the EN 1998 standard can be entered.

You need to calculate/enter the horizontal design acceleration in the plateau area of the response spectrum. Based on the location, the locations soil type and the importance class of your vessel.

This is a conservative approach.



If you know the eigenfrequency of your system, a different value can be entered, based on your calculations.

This is a complex calculation that hinges on various factors. For additional assistance, click on "more info.", or contact the amphora admin if Solico’s assistance is required.

9.3. Laminate thickness

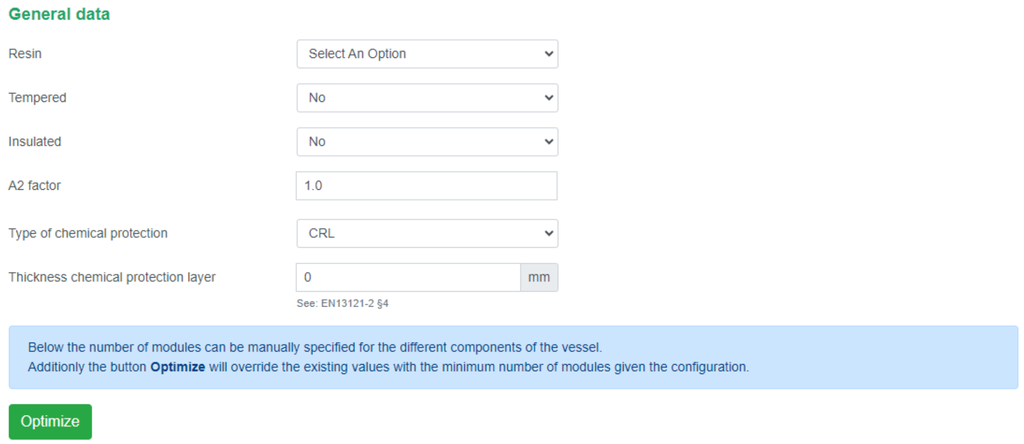
Once the loads of the tank/silo are complete, the laminates can be defined. Click on the 'Laminate thickness' header, after you confirmed your loads by clicking 'update'.

9.3.1. General

Start by entering general data, selecting the resin from your database, and indicating whether the silo is tempered/cured and insulated (yes/no impacts self-weight for structural calculations, and the calculation of the A_3-factor).

Address the A_2-factor for chemical resistance, typically set to one for dry bulk materials (silos), but depending on the type of medium for tanks storing liquids.

The type and thickness of the chemical protection barrier has to be added. Choose between a single protection layer (SPL), a chemical barrier layer (CBL) and a thermoplastic protection layer (TPL). The type and required thickness of this layer is prescribed by EN13121-2, otherwise a resin advice has to be obtained through your resin provider.



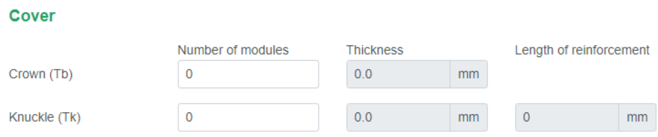
After entering all previous data, there are 2 ways to determine the required structural laminate thicknesses for your project:

1. Specify the number of modules yourself, and click 'analyse'
2. or let the Amphora algorithm determine the optimum thicknesses by clicking "optimize

! Amphora only calculates the structural thicknesses. All thicknesses visible in tables, determined by Amphora's optimisation routine, or entered manually are structural thicknesses, EXCLUDING the required thickness for the chemical protection layer.

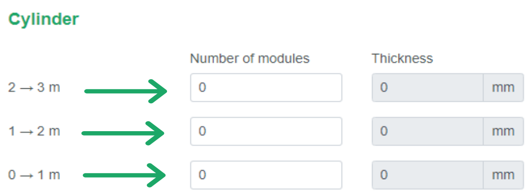
9.3.2. Cover

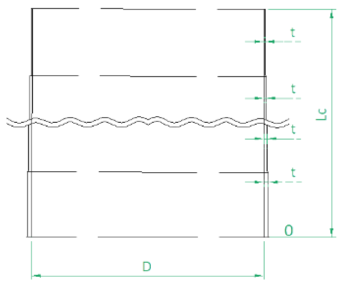
The cover has two sections: the crown and the knuckle. Input the number of modules, representing the number of layers you construct. Thickness is automatically calculated based on the module thicknesses listed in your material database.



9.3.3. Cylinder

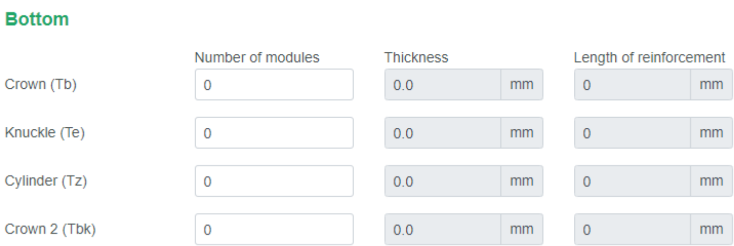
Amphora automatically divides the cylinder into slices (or sections), the length of a slice depends on the total length of the cylinder. Adjust the number of laminate modules in each section to control the structural thickness.

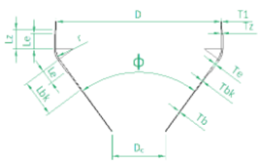




9.3.4. Bottom

Start with the crown thickness and input the number of modules for each hopper section, as indicated in the figure.





9.3.5. Support

Proceed to input support and anchoring for uplift, dependent on the support type chosen earlier. For the skirt, enter the number of modules for the skirt, skirt upper part, and skirt lower part. Anchoring for uplift may not be applicable for some silo's, contingent on the selected support type during geometry calculations.

10. Report

Amphora can report results in 2 ways:

1. A swift overview of the performance of your vessel can be found in the on-screen report
2. The downloadable report, which is a much more elaborate report that can be provided to governing bodies

10.1. On screen report

The report is divided into two primary sections: general properties and results, each focusing on specific aspects of the silo/tank. Ensure that unity check values stay below 1, indicating the potential need for adjustments, such as altering laminate thickness.

Commence with the general property section, detailing geometry information. Progress to the cover overview, examining geometry, critical loads, and unity checks for strength, strain, and stability. Proceed to cylinder results, presenting thickness, strength, strain, and stability for both full and empty silos, including critical vacuum and external pressure (Pz) for radial stability. Unity checks for strength, strain, and stability must remain below one.

Move on to the bottom of the silo, analysing geometry, critical loads, and unity checks for strength, strain, and stability. Repeat the process for the skirt, considering geometry, critical loads, unity check, and dedicated thickness.

For anchoring, evaluate geometry, critical loads, and unity checks, noting tensile strength per anchor, bearing strength for bolts, and unity check for connection laminate. Ensure all unity checks are below one.

In cases where unity check values exceed one, use the "Optimize" button or manually adjust laminate thicknesses for compliance. Reassess unity checks to guarantee acceptability. Once all unity checks are below one, the report aligns with the required codes.

This comprehensive report provides the necessary calculations for silo construction and accurate cost estimation. Congratulations on mastering the calculation process in Amphora!

! Amphora will display unity checks ≥ 1 always in red.

10.2. Downloadable Report

The downloadable report mirrors the on-screen version precisely. Nevertheless, opting for the downloadable report offers distinct advantages, as it furnishes a PDF format that can be effortlessly shared with clients or submitted to the relevant authorities.