

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

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

Amphora@solico.nl



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13.3. Materials



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
- 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.

					Projects Materials	←
r	Materials List					
\longrightarrow	aminates					
L	Jser	Name	Description	Type of laminate	!	
R	esins					
	eate new resin					
Us	<u>ser</u>	Name	Resin type	HDT of resin Ultima	te strain	

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).

	Materials List			
\rightarrow	Laminates Create new laminate			
	User	<u>Name</u>	Description	<u>Type of laminate</u>
	Insert laminate ma	terial		
	Hume			
	Laminates			
	Description			
				10
	Module thickness			mm
	Thickness of pre-run laminate			mm
	Type of laminate		Select An Option	~



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.

Material properties			
Tensile modulus axial	\$	MPa	
Tensile strength axial		MPa	
Bending modulus axial		MPa	
Bending strength axial		MPa	
Tensile modulus circumferential		MPa	
Tensile strength circumferential		MPa	
Bending modulus circumferential		MPa	
Bending strength circumferential		MPa	
Inter laminar shear strength		MPa	
Density	Rho	kg/m ³	
Thermal expansion coefficient	alfa	10 ⁻⁶ /K	
Bearing strength		MPa	
Partial influence factors			
Influence of test verification	A ₁		The A-1 factor influences the minimum design factors for strength
Axial, strength	A _{5,a,B}		
Circumferential, strength	A _{5,c,B}		Amphora automatically compensates the A5-design factor
Axial, stability	A _{5,a,I}		when the minimum K- and F-factors are not met according to EN13121- 3. and stability.
Circumferential, stability	A _{5,c,I}		
	Cancel	Insert	

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.

\rightarrow	Insert resin	
	Resin type	Select An Option
	HDT of resin	٦°
	Ultimate strain	%
		Cancel

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 vour Amphora admin.								
				\rightarrow	Projects	Materials	Amphora@solico.nl	Log of
Projects Lis	St Jump to: 62300761							
User	Created at	Name	Product type	Description				
	Create Project Name Product type Length of cylinder Diameter Description	Silo						

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.

Projects List						
Create new project	Jump to: Test					
<u>User</u>	Created at	<u>Name</u>	Product type	Description		
Amphora@solico.nl	2023-12-27 09:17:47Z	Test	Silo		\rightarrow	Edit Rename Delete



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.

6.1.1.1. Semi Elliptical Cover





6.1.1.2. Torispherical Cover

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



6.1.1.3. Torispherical Cover with user input

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

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	~

6.1.1.4. Conical Cover

Cover

Type of cover	Conical cover	~
Ventilated vessel	No	*
Angle	Φ 75	۰
Knuckle radius	r 0	mm
Cover material	Select An Option	~



6.1.1.5. <u>No Cover</u>

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.



6.1.2. Cylinder

Proceed with entering the details about the cylinder. The length and diameter have already been prefilled 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.

Cylinder				1
Length of cylinder	LC 3000	mm		
Diameter	D 2000 \$	mm		2
Volume	VI 0	m ³		
Cylinder material	Select An Option	~		<u>, </u>
Note that Amphora automatically	determines the number o	f sections to divide the	e cylinder. This is	based on the 'length

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. <u>Hopper</u>

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.

Bottom			D
Type of bottom	Hopper	~	1
Angle	Φ 70	0	•
Knuckle radius	r 0	mm	X
Diameter of outlet	Do 0	mm	- D _o
Bottom material	Select An Option	~	

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.



Support								
Type of support	Full	y supported skirt	~		1	Tsku		
Length of skirt	Lsk	2000	mm					
Width of opening	Во	0	mm	×		Tsk		
	Germa more d with.	n authorities do not allow this calculation etailed analysis is demanded which Solic	approaci o Engine	h for large cut-outs. A sering can support you			┝	
Support material	Sel	ect An Option	~		lower			Tsk lower
					Ls I			

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 cutout.

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 n	nm	
Length of skirt	Lsk 300 n	nm	b
Number of supports	Ns 4		
Support width	b 300 n	nm	우 ·
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.

Anchoring for uplift		
Type of anchoring	Anchoring bracket laminated	~
Number of anchors	4	
Thickness of overlaminate	t O	mm
Anchor width overlaminate	b 0	mm
Shear surface area overlaminate	A 0	mm ²

6.1.5.2. Anchoring bracket bolted

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

b = b1 + b2 + b3 + b4



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



6.1.5.3. 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	+

6.1.5.4. Clamp bracket on ring

The lower edge of the vessel is equipped with a 'nose', in combination with the (steel) clamp brackets 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 r	m		
Length of bracket	I 125 r	m	ے	
Width of bracket	w 100 r	m	Dn +	
Height of anchor/nose	h 0 r	m	+	

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 ac	count any exter	nal nozz	le loads.					
Cut-outs									
Compensation laminate		Select An Option		~					
Description	Diameter			Position		Height on cylinder			
	Branch diamete	er	mm	Cylinder	~	Height on cylinder	n	ım Ins	sert



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.

Load from content (according to EN 1991-4)

Type of medium		
Density	1200	kg/m ³
Lateral pressure	K _m 0.5	
Lateral pressure	a _K 1.5	
Wall friction	μ _m 0.39	
Wall friction	a _µ 1.4	
Bottom load magnifying factor	Cb 1.3 See EN1991-4 § 6.1.2	
Design temperature	More info T _D 40	°C

Table E.1: Particulate solids properties												
Type of particulate solid ^{d, e}	Unit w	eight ^b Y	Angle of repose \$	Angle of internal friction \$\vec{\vec{\vec{\vec{\vec{\vec{\vec{		Lateral pressure ratio K		Wall friction coefficient ⁶ μ $(\mu = \tan \phi_w)$			ient ^e	Patch load solid reference factor C_{op}
	7,	γ.,	ø,	Pin	a_{ϕ}	К,,,	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	6,0	22,0	40	35	1,3	0,50	1,5	0,32	0,39	0,50	1,40	1,0
Apprepate	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 O	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 b	15,0	18,0	47	40	1,20	0,38	1,31	0,46	0,56	0,62	1,07	0,7
Coal O	7.0	10.0	36	31	1,16	0.52	1.15	0.44	0.49	0.59	1.12	0.6
Coal, powdered O	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 O	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 O	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 O	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 O	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 tab	sle does r	tot contai	n the mater	ial to be st	ored, testi	ing shou	ld be und	ertaken.				
 For situations wh design are mittor However, they will 	ere it is , the pro ill lead to	difficult perties o very une	to justify th f the "defa conomic d	e cost of alt materia esigns for	testing, be al" may b large silos	cause th e used. , and ter	e cost in For smal sting show	plication i installa ild alway	is of usin tions, the s be peef	ig a wide se prope ierred.	property rties may	range for the be adequate.
^b The unit weight value y ₂ is provid	of the so led in Tal	hid χ_0 is ble E.1 to	the upper c assist in es	haracteris timating 0	tic value, he require	to be us d volum	ed for al e of a sile	calculat that will	ions of a I have a d	etions. T lefined ca	he lower ipacity.	characteristic
 Effective wall frie 	ction for	wall Typ	e D4 (com	eated wall	D may be	found us	ine the n	ethed de	fined in	Annes D	D.2.	
^d Solids in this table	e that are	known i	o be suscep	stible to de	ist explosi	on are id	lentified	by the sy	mbol O			
^e Solids that are su	sceptible	to mecha	mical interl	ocking are	identified	i by the	symbol t					



6.2.2. Pressure

Live load on cover			
Distributed load	Pacces	1.5	kN/m ²

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.

	Pressure						
	Design pressure	P _i 0.005 bar	Short term 🗸				
	Design vacuum	Pe 0.003 bar	Short term 🗸				
		More info					
	Maximum reduced explosion overpressure	P _{red,max} 0	bar				
	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.

Additional mass		
On cover	W _{cover} 0	kg
On top of cylinder	Qcylinder 0	кg
On cylinder wall	Wcylinder 0	kg/m
		_
On outlet of hopper	Whopper 0	kg



6.2.4.1. Additional Mass on cover



6.2.4.2. Additional Mass on top of cylinder

On top of cylinder



6.2.4.3. Additional Mass on outside wall

On outside wall





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. : 500kg π · 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.

Wind and snow (according E	EN 1991-1-3 and EN 1991-1-4)
Country	Netherlands	~
Wind zone	Ι	~
Terrain category	0	~
Wind force coefficient	Standard	~ ~

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.



Seismic (according EN 1998-1 and EN 1998-4)							
More info							
Horizontal design acceleration, plateau area	S _d (T ₁)	0	m/s ²				

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 A₂-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.

General data						
Resin	Select An Option	~				
Tempered	No	~				
Insulated	No	~				
A2 factor	1.0					
Type of chemical protection	CRL	~				
Thickness chemical protection layer	0	mm				
	See: EN13121-2 §4					
Below the number of modules can be manually specified for the different components of the vessel. Additionly the button Optimize will override the existing values with the minimum number of modules given the configuration.						
Optimize						

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.

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

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.

Bottom						D
	Number of modules	Thickness		Length of reinfo	rcement	57
Crown (Tb)	0	0.0	mm	0	mm	the the Xa
Knuckle (Te)	0	0.0	mm	0	mm	
Cylinder (Tz)	0	0.0	mm	0	mm	De
Crown 2 (Tbk)	0	0.0	mm	0	mm	



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.

Number of modules			Length of reinforcement		
0	0.0	mm			
	0.0		0		
0	0.0	mm	0	mm	
0	0.0	mm	0	mm	
	Number of modules 0 0 0 0	Number of modules Thickness 0 0.0 0 0.0 0 0.0	Number of modules Thickness 0 0.0 mm 0 0.0 mm 0 0.0 mm	Number of modules Thickness Length of reinform 0 0.0 mm 0 0 0.0 mm 0 0 0.0 mm 0	



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. <u>No Cover</u>

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 prefilled 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.

Cylinder			
Length of cylinder	LC	3000	mm
Diameter	D	2000	\$ mm
Volume	VI	0	m ³
Cylinder material	Se	elect An Option	~

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. <u>Hopper</u>

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.



Bottom

Type of bottom	Hopper	~
Angle	Φ 70	٥
Knuckle radius	r 0	mm
Diameter of outlet	Do 0	mm
Bottom material	Select An Option	~



7.1.3.2. Semi elliptical bottom

Choose the bottom material.

Bottom			D
Type of bottom	Semi elliptical R=0.8xD	•	-
Bottom material	Select An Option	•	R = 0.964AD

7.1.3.3. Torishpherical bottom

Choose the bottom material.

Bottom D Torispherical R=D Type of bottom ~ Bottom material Select An Option ~ R = D

7.1.3.4. Flat bottom in membrane design

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

I



Bottom		
Type of bottom	Flat bottom in membrane design	~
Knuckle radius	r 0	mm
Bottom material	Select An Option	~

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 r	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.

Support							
Type of support	Full	y supported skirt	~		1	Tsku	
Length of skirt	Lsk	2000	mm				
Width of opening	Во	0	mm	×	1	Tsk	
	German more de with.	n authorities do not allow this calculation etailed analysis is demanded which Solic	approac o Engine	h for large cut-outs. A eering can support you	ʻ	~	~
Support material	Sele	ect An Option	~		ower		Tsk lower
					ĽŽ	[

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 cutout.

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		b b
Number of supports	NS 4	,		000
Support width	b 300	mm	윤	
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		Π	
Type of support	Support with ring girder on legs		()
Length of legs	Lp 2000 mm		b
Number of legs	Np 4	-	000
Support width per leg	b 300 mm		
Support material	Select An Option 🗸	/	Гр
		+	

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.



Anchoring for uplift Anchoring bracket laminated Type of anchoring Α Number of anchors 4 t t O mm Thickness of overlaminate b2 b1 b 0 Anchor width overlaminate mm b3 b4 A 0 mm² Shear surface area overlaminate

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	



b = b1 + b2 + b3 + b4

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.





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 no	t take into ac	count any extern	nal nozz	le loads.					
Cut-outs									
Compensation laminate		Select An Option		•					
Description	Diameter			Position		Height on cylinder			
	Branch diamete	ſ	mm	Cylinder	~	Height on cylinder	r	nm Insert	



7.2. Loads

Live load on cover			
Distributed load	Pacces	1.5	kN/m ²

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

Load from content		
Type of medium		
Density	1200	kg/m ³
Design temperature	T _D 40	°C

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.

Pressure	
Design pressure	Pi 0.005 bar Short term ✓
Design vacuum	Pe 0.003 bar Short term V
Maximum reduced explosion overpressure	More info
	Freq,max 0 Dai
Amphora will always consider the minimurto zero by the user.	m pressures prescribed by the standard, even when the pressures are set

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	Whopper 0	kg

7.2.4.1. Additional Mass on cover



7.2.4.2. Additional Mass on top of cylinder

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



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.

Wind and snow (according EN 1991	-1-3 and EN 1991-1-4)
Country	Netherlands	~
Wind zone	1	~
Terrain category	0	~
Wind force coefficient	Standard	×>



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	Thickness		orcement
Crown (Tb)	0	0.0	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.



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						D
	Number of modules	Thickness		Length of reinf	forcement	2 9 1 Tz
Crown (Tb)	0	0.0	mm	0	mm	the A
Knuckle (Te)	0	0.0	mm	0	mm	The the test
Cylinder (Tz)	0	0.0	mm	0	mm	Dc
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.

Number of modules	Thickness		Length of reinfo	rcement
0	0.0	mm		
	0.0		0	
0	0.0	mm	0	mm
0	0.0	mm	0	mm
	Number of modules 0 0 0 0	Number of modules Thickness 0 0.0 0 0.0 0 0.0	Number of modules Thickness 0 0.0 mm 0 0.0 mm 0 0.0 mm	Number of modules Thickness Length of reinform 0 0.0 mm 0 0 0.0 mm 0 0 0.0 mm 0



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

Cover		
Type of cover	Semi elliptical R=0.8xD	~
Ventilated vessel	No	~
Cover material	Select An Option	~

8.1.1.2. Torispherical Cover

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





8.1.1.3. Torispherical Cover with user input

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

Select An Option

~

~

mm

mm

~

Cover Torisperical (user input) Type of cover Torisperical (user input) Ventilated vessel No Crown radius R 2000 Knuckle radius r 50



8.1.1.4. Conical Cover

Cover

Cover material

Type of cover	Conical cover	~
Vantilated vessel	No	
ventilated vessel	NO	
Angle	Φ 75	٥
Knuckle radius	r 0	mm
Cover material	Select An Option	~



8.1.1.5. <u>No Cover</u>

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 prefilled 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.

Cylinder		
Length of cylinder	LC 3000	mm
Diameter	D 2000 \$	mm
Volume	VI 0	m ³
Cylinder material	Select An Option	~

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. <u>Ribs</u>

The rib stiffened cylinder is stiffened by ribs.

Rectangular solid rib

The first option is the rectangular solid GFRP rib

Rib

Type of rib	Rectangular solid rib	~
Width	0	mm
Height	0	mm
Distance between 2 stiffeners	LS 0	mm
Rib material	Select An Option	~





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	Η 0	mm
Thickness	t O	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	1 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.

Bottom			D
Type of bottom	Hopper	*	5
Angle	Φ 70	0	φ.
Knuckle radius	r 0	mm	$ \rightarrow $ $ \times $ $ > $
Diameter of outlet	Do 0	mm	
Bottom material	Select An Option	~	



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.

Support				
Type of support	Fully supported skirt	~		Tsku
Length of skirt	Lsk 2000	mm		
Width of opening	Во 0	mm	×	Tsk
	German authorities do not allow this calculation more detailed analysis is demanded which Solid with.	approach for large cut-outs. A co Engineering can support you	- L	~
Support material	Select An Option	~	lower	Tsk lower
			Lsk	

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 cutout.



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	b
Number of supports	Ns 4	1	
Support width	b 300	mm	유 문
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				П
Type of support	Support with ring girder on legs	~		
Length of legs	Lp 2000	mm		
Number of legs	Np 4		-	F
Support width per leg	b 300	mm		
Support material	Select An Option	~		위



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	<u>n</u>
Number of bolts per anchor	n 0	n
		1-0-0

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	I 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.





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 n	ot take into ac	count any exter	nal nozz	le loads.					
Cut-outs Compensation laminate		Select An Option		~					
Description	Diameter			Position		Height on cylinder			
	Branch diamete	ſ	mm	Cylinder	~	Height on cylinder	n	ım Insert	



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.

Load from content (according to EN 1991-4)

						Table	E.1: Pa	rticulate	solid:	s prope	rties				
Type of medium			Type of particulate solid ^{d, e}	Unit w	eight ^b	Angle of repose \$,	Angle of fric	f internal tion Øj	Late pres ra	eral isure tio K	Wall	friction	coeffici u an ϕ_{w})	ent ^e	Patch load solid reference factor
Density	1200	kg/m ³		η,	r _u	θ,	¢ _{inv}	aø	<i>K</i> ₁₀	a _K	Wall type D1	Wall type D2	Wall type D3	aµ	Cop
Lateral pressure	Km 0.5		Default material *	Lower kN/m ³ 6,0	Upper kN/m ³ 22,0	degrees 40	Mean degrees 35	Factor 1,3	Mean 0,50	Factor	Mean 0,32	Mcan 0,39	Mean 0,50	Factor 1,40	1,0
			Aggregate	17,0 10,0	18,0 12,0	36 36	31	1,16	0,52	1,15	0,39 0,41	0,49	0,59	1,12	0,4
Lateral pressure	a _K 1.5		Animal feed mix Animal feed pellets Barley O	5,0 6,5 7,0	6,0 8,0 8,0	39 37 31	36 35 28	1,08 1,06 1,14	0,45 0,47 0,59	1,10 1,07 1,11	0,22 0,23 0,24	0,30 0,28 0,33	0,43 0,37 0,48	1,28 1,20 1,16	1,0 0,7 0,5
Mall frinklass			Cement clinker 1 Coal O	13,0 15,0 7,0	16,0 18,0 10,0	36 47 36	30 40 31	1,22 1,20 1,16	0,54 0,38 0,52	1,20 1,31 1,15	0,41 0,46 0,44	0,46 0,56 0,49	0,51 0,62 0,59	1,07 1,07 1,12	0,5 0,7 0,6
wall friction	μ _m 0.39		Coal, powdered O Coke Flyash	6,0 6,5 8,0	8,0 8,0 15,0	34 36 41	27 31 35	1,26 1,16 1,16	0,58 0,52 0,46	1,20 1,15 1,20	0,41 0,49 0,51	0,51 0,54 0,62	0,56 0,59 0,72 0,19	1,07 1,12 1,07	0,5
Wall friction	a _µ 1.4		Iron ore pellets Lime, hydrated Limestone powder	19,0 6,0 11,0	22,0 8,0 13,0	36 34 36	31 27 30	1,16 1,26 1,22	0,52 0,58 0,54	1,15 1,20 1,20	0,49 0,36 0,41	0,54 0,41 0,51	0,59 0,51 0,56	1,10	0,5 0,6 0,5
			Maize O Phosphate Potatoes	7,0 16,0 6,0	8,0 22,0 8,0	35 34 34	31 29 30	1,14 1,18 1,12	0,53 0,56 0,54	1,14 1,15 1,11	0,22 0,39 0,33	0,36 0,49 0,38	0,53 0,54 0,48	1,24 1,12 1,16	0,9 0,5 0,5
Bottom load magnifying factor	Cb 1.3		Sand Slag clinkers Soya beans	14,0 10,5 7,0 8,0	16,0 12,0 8,0	39 39 29	36 36 25	1,09 1,09 1,16	0,45 0,45 0,63	1,11 1,11 1,11	0,38 0,48 0,24 0.46	0,48 0,57 0,38	0,57 0,67 0,48 0.56	1,16 1,16 1,16	0.4 0.6 0.5
	See EN1991-4 § 6.1.2 More info		Sugarbeet pellets Wheat O	6,5 7,5	7,0 9,0	36 34	31 30	1,16 1,12	0,52	1,15 1,11	0,35	0,44	0,54 0,57	1,12	0,5
			For situations wh design are mittor	ere it is c , the pro-	fifficult i perties of	to justify the	se cost of alt materi	testing, ber	cause the used.	te cost in For smal	plication installa	ns of usin dions, the	ig a wide ise prope	property rties may	/ range for the y be adequate.
Design temperature	T _D 40	°C	 However, they will The unit weight of value y_g is provid Effective wall frie 	Il lead to of the sol ed in Tab	id χ_0 is 1 de E.1 to wall Typ	the upper cl assist in es to D4 (corru-	haracterist timating t tgated wal	large silos, tic value, to the required II) may be f	o be use f volume found us	ed for all e of a sile sing the n	ild alway I calculat > that will nethed de	s be prefi ions of a f have a c rfined in	rred. ctions. TI lefined ca Annex D	he lower ipacity. D.2.	characteristic

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.



Pressure					
Design pressure	Pi	0.005	bar	Short term	~
Design vacuum	Pe	0.003	bar	Short term	~
	More	e info			
Maximum reduced explosion overpressure	P _{red,r}	max 0			bar
Amphora will always consider the minimum	n pres	sures p	orescrib	ed by the	sta

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.

Additional mass		
On cover	W _{cover} 0	kg
On top of cylinder	Q _{cylinder} 0	kg
On cylinder wall	Wcylinder 0	kg/m
On outlet of hopper	Whopper 0	kg

8.2.4.1. Additional Mass on cover

On cover



W cover [kg] = load is distributed over cover surface



8.2.4.2. Additional Mass on top of cylinder

On top of cylinder



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



8.2.4.3. Additional Mass on outside wall

On outside wall



8.2.4.4. Additional Mass on outlet of hopper

On outlet of hopper



W hopper [kg] = load is distributed over edge of outlet E.g.: 500kg $\pi \cdot D$ hopper outlet



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.

Wind and snow (according	EN 1991-1-3 and EN 1991-1-4)	1
Country	Netherlands	*
Wind zone	1	~
Terrain category	0	~
Wind force coefficient	Standard	~ <u> </u>

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.

Seismic (according EN 1998-1 and EN 1998-4)							
More info							
Horizontal design acceleration, plateau area	S _d (T ₁)	0	m/s ²				

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 A₂-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.

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

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.

Bottom						D
	Number of modules	Thickness		Length of reinf	forcement	2 9 1 Tz
Crown (Tb)	0	0.0	mm	0	mm	the A
Knuckle (Te)	0	0.0	mm	0	mm	The the test
Cylinder (Tz)	0	0.0	mm	0	mm	Dc
Crown 2 (Tbk)	0	0.0	mm	0	mm	



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.

Number of modules	Thickness		Length of reinfo	rcement
0	0.0	mm		
	0.0		0	
0	0.0	mm	0	mm
0	0.0	mm	0	mm
	Number of modules 0 0 0 0	Number of modules Thickness 0 0.0 0 0.0 0 0.0	Number of modules Thickness 0 0.0 mm 0 0.0 mm 0 0.0 mm	Number of modules Thickness Length of reinform 0 0.0 mm 0 0 0.0 mm 0 0 0.0 mm 0



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

Cover		
Type of cover	Semi elliptical R=0.8xD	~
Ventilated vessel	No	~
Cover material	Select An Option	~

r = 0.154xD 00 "" D

9.1.1.2. Torispherical Cover

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





9.1.1.3. 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	~



9.1.1.4. Conical Cover

Cover		
Type of cover	Conical cover	~
Ventilated vessel	No	~
Angle	Φ 75	٥
Knuckle radius	r 0	mm
Cover material	Select An Option	~



9.1.1.5. <u>No Cover</u>

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.

9.1.2. Cylinder

Proceed with entering the details about the cylinder. The length and diameter have already been prefilled 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.



Cylinder		
Length of cylinder	LC 3000	mm
Diameter	D 2000	¢ mm
Volume	VI 0	m ³
Cylinder material	Select An Option	~

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. <u>Ribs</u>

The rib stiffened cylinder is stiffened by ribs.

Rectangular solid rib

The first option is the rectangular solid GFRP rib

Rib

Type of rib	Rectangular solid rib	~	
Vidth	0	mm	
leight	0	mm	
Distance between 2 stiffeners	LS 0	mm	
lib material	Select An Option	~	

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	Н 0	mm
Thickness	t O	mm
Distance between 2 stiffeners	LS 0	mm
Rib material	Select An Option	~

н

B1



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	1 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. <u>Hopper</u>

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.

Bottom			D
Type of bottom	Hopper	~	5
Angle	Φ 70	0	• /
Knuckle radius	r 0	mm	X
Diameter of outlet	Do 0	mm	Do
Bottom material	Select An Option	~	

9.1.3.2. Semi elliptical bottom

Choose the bottom material.

ottom			D
pe of bottom	Semi elliptical R=0.8xD	~	•
naterial	Select An Option	*	r=0.154XD

9.1.3.3. Torishpherical bottom

Choose the bottom material.

Bottom			D
Type of bottom	Torispherical R=D	~	•
Bottom material	Select An Option	~	r ante

9.1.3.4. Flat bottom in membrane design

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



Bottom		
Type of bottom	Flat bottom in membrane design	~
Knuckle radius	r 0	mm
Bottom material	Select An Option	~

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 m	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.

Support			
Type of support	Fully supported skirt	~	Tsku
Length of skirt	Lsk 2000	mm	
Width of opening	Во 0	mm	Tsk
	German authorities do not allow this calculatio more detailed analysis is demanded which Sol with.	n approach for large cut-outs. A	
Support material	Select An Option	~	Tsk lower
		_	Ľ.

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 cutout.

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 mr	m
Length of skirt	Lsk 300 mr	m b
Number of supports	Ns 4	
Support width	b 300 mr	m e
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		П	
Type of support	Support with ring girder on legs	~	
Length of legs	Lp 2000	nm	b
Number of legs	Np 4		000
Support width per leg	b 300	nm	
Support material	Select An Option	· / 4	L D

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.

Anchoring for uplift				
Type of anchoring	Anchoring bracket laminated	~		Δ
Number of anchors	4	t	-	
Thickness of overlaminate	t o	mm		b1 b2
Anchor width overlaminate	b 0	mm		b3
Shear surface area overlaminate	A 0	mm ²		
				b = b1 + b2 + b3 + b4

9.1.5.2. 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 r	nm
Number of bolts per anchor	n 0	



9.1.5.3. 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	I 125 mm	
Number of bolts per anchor	n 0	+

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	i 125 mm	
Width of bracket	w 100 mm	
Height of anchor/nose	h 0 mn	+

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 ac	count any exter	rnal nozz	zle loads.				
Cut-outs								
Compensation laminate		Select An Option		~				
Description	Diameter			Position		Height on cylinder		
	Branch diamete	ſ	mm	Cylinder	~	Height on cylinder	mm	Insert



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

Load from content		
Type of medium		
Density	1200	kg/m ³
Design temperature	T _D 40	°C

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.

Pressure	
Design pressure	P _i 0.005 bar Short term •
Design vacuum	Pe 0.003 bar Short term V
	More info
Maximum reduced explosion overpressure	P _{red,max} 0 bar

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	Pacces	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	Wcylinder 0	kg/m
On outlet of hopper	Whopper 0	kg

9.2.4.1. Additional Mass on cover

D

On cover

W cover [kg] = load is distributed over cover surface





9.2.4.2. Additional Mass on top of cylinder

On top of cylinder



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



9.2.4.3. Additional Mass on outside wall

On outside wall



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.: 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.

Wind and snow (according	EN 1991-1-3 and EN 1991-1-4)	1
Country	Netherlands	*
Wind zone	1	~
Terrain category	0	~
Wind force coefficient	Standard	~ <u> </u>

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.

Seismic (according EN 1998-1 and EN 1998-4)							
More info							
Horizontal design acceleration, plateau area	S _d (T ₁)	0	m/s ²				

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.

General data		
Resin	Select An Option	~
Tempered	No	~
Insulated	No	~
A2 factor	1.0	
Type of chemical protection	CRL	~
Thickness chemical protection layer	0	mm
	See: EN13121-2 §4	
Below the number of modules can be manual Additionly the button Optimize will override the	ly specified for the different component e existing values with the minimum nur	s of the nber of
Optimize		

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.

Cover					
	Number of modules	Thickness		Length of reinford	cement
Crown (Tb)	0	0.0 mm			
Knuckle (Tk)	0	0.0	mm	0	mm

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.

Bottom						D
	Number of modules	Thickness		Length of reinf	forcement	2 9 1 Tz
Crown (Tb)	0	0.0	mm	0	mm	the A
Knuckle (Te)	0	0.0	mm	0	mm	The the test
Cylinder (Tz)	0	0.0	mm	0	mm	Dc
Crown 2 (Tbk)	0	0.0	mm	0	mm	



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.

Support					
	Number of modules	Thickness		Length of reinf	orcement
Skirt (Tsk)	0	0.0	mm		
Obid upper and (Talue)	0	0.0		0	
Skirt upper part (Tsku)	0	0.0	mm	0	mm
Skirt lower part (S _{Skl})	0	0.0	mm	0	mm



10. Horizontal Tanks

10.1. Geometry

First, establish the geometry of the tank or silo.

10.1.1. Cover

Start by selecting a cover type from the dropdown menu, which shows several geometric options, including the choice of having no cover. Available types: Semi-Elliptical, Torispherical, Torispherical user input.



10.1.2. Cylinder

Cylinder			
Length of cylinder	Lc 6000	mm	
Diameter	D 2000	mm	
			(
Volume	VI 0	m ³	
Cylinder material	Select An Option	~	

10.1.3. Saddle

Analyses up to 8 saddles is possible

Saddle	
Number of saddles	Ns 2
Distance between saddles	Ls 3600 mm
	Equal distance between all saddles is considered
Type of saddle	Flexible supports or slings
	More info
Saddle angle	Φ 180 °
Width of saddles	Bs 200 mm





Saddle type more info

For the purposes of this European Standard, the definitions of the two types of saddle configuration are:

- c) a rigid saddle is one where over the area of support the vessel shell is constrained to the saddle. Such saddles are usually manufactured from either a solid steel fabrication, or pre-cast in concrete.
- d) a soft saddle is one where at the area of support, the saddle supporting strap is flexible allowing the saddle and vessel to deform together.

10.1.4. Cut-outs

Cut-outs		
Compensation laminate	Select An Option	~
Description	Diameter	Position
	Branch diameter	mm Cylinder V Insert
This is s	slightly different from the verti	cal tank. Only the cylinder and cover positions are available.

10.2. Loads

Once the geometry of the tank 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'.

10.2.1. 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.

10.2.2. 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.

Live load on cover			
Distributed load	Pacces	1.5	kN/m ²



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.

Pressure		
Design pressure	P _i 0.005 bar	Short term 🗸
Design vacuum	P _e 0.003 bar	Short term 🖌
	More info	
Maximum reduced explosion overpressure	P _{red,max} 0	bar

10.2.3. Platform

_ . . .

Additional mass considered in calculations.

Platform			Length Width
Platform present on top	Yes	~	
Platform total weight	0	kg	
Platform width	0	mm	
Platform length	0	mm	

10.2.4. Live load on platform

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 on the platform area.

10.2.5. 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.

Wind and snow (according	J EN 1991-1-3 and EN 1991-1-4)
Country	Netherlands	~
Wind zone	1	*
Terrain category	0	~
Wind force coefficient	Standard	~ ~

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.

10.2.6. 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.

Seismic (according EN 1998-1 and EN 1998-4)				
More info				
Horizontal design acceleration, plateau area	S _d (T ₁) 0	m/s ²		

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.

10.3. 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'.

10.3.1. 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 A3-factor).



Address the A2-factor for chemical resistance, typically set to one for dry bulk materials (silos), but depending on the type of medium for tanks storing liquids.

Resin	Select An Option	~			
Tempered	No	~			
less deterd					
Insulated	NO	~			
A2 factor	1.0				
Type of chemical protection	CRL	~			
Thickness chemical protection layer	0	mm			
	See: EN13121-2 §4				
Below the number of modules can be n Additionly the button Optimize will over	anually specified for the different co ride the existing values with the min	imponents of the vessel.	s given the configu	iration	
, adden, ale saler optimize will over	has the chicking raides with the min		s grott the conlige		

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.

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

10.3.2. 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 reinforce	ement
Crown (Tb)	0	0.0	mm		
Knuckle (Tk)	0	0.0	mm	0	mm



10.3.3. Cylinder

Cylinder

Cylinder

Number of modules

0

0.0 mm





11. Rib Stiffened Horizontal Tank

11.1. 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.

11.1.1. Cover

Start by selecting a cover type from the dropdown menu, which shows several geometric options, including the choice of having no cover. Available types: Semi-Elliptical, Torispherical, Torispherical user input.



11.1.2. Cylinder

Cylinder

Length of cylinder	Lc 6000	mm
Diameter	D 2000	mm
Volume	VI 0	m ³
Cylinder material	Select An Option	~



11.1.3. Saddle

Saddle Number

Number of saddles	Ns 2
Distance between saddles	Ls 3600
	Equal distance between all saddles is considered
Type of saddle	Flexible supports or slings
	More info
Saddle angle	Φ 180
Width of saddles	Bs 200



mm

~

۰

mm



Saddle type more info

For the purposes of this European Standard, the definitions of the two types of saddle configuration are:

- c) a rigid saddle is one where over the area of support the vessel shell is constrained to the saddle. Such saddles are usually manufactured from either a solid steel fabrication, or pre-cast in concrete.
- d) a soft saddle is one where at the area of support, the saddle supporting strap is flexible allowing the saddle and vessel to deform together.

11.1.4. Ring

Currently only one type of ring available for calculations (Rectangular solid ring)

Ring		
Type of ring	Rectangular solid ring	~
Ring in between saddles	No	~
Ring on cylinder	Yes	~
	More info	
Width	400	mm
Ring material	Winding Material	~



11.1.4.1. Ring in between saddles

For stability purposes, extra rings can be added in between saddle rings for the calculation.

11.1.4.2. Ring on cylinder option

11.1.5. Cut-outs

Ring on cylinder n Cut-outs	nore info			
Compensation laminate	Select An Option	~		
Description	Diameter		Position	
	Branch diameter	mm	Cylinder	✓ Insert
N.		20,	.▲	

Figure 44 — Effective dimension of the stiffener at the dome end position

Slightly different from vertical. Only Cylinder and cover position options are available.



11.2. Loads

Live load on cover			
Distributed load	Pacces	1.5	kN/m ²

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'.

11.2.1. Loads from content

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

Load from content		
Type of medium		
Density	1200	kg/m ³
Design temperature	T _D 40	°C

11.2.2. 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.

11.2.3. Platform

Additional mass considered in calculations.

Platform			Length	Width
Platform present on top	Yes	~		
Platform total weight	0	kg		R
Platform width	0	mm		\bigcirc
Platform length	0	mm		

11.2.4. Live load on platform

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 on the platform area.



11.2.5. 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.

Wind and snow (according EN 1991-1-3 and EN 1991-1-4)

Country	Netherlands	~	
Wind zone	I	*	
Terrain category	0	 Enter the wind standard for standard 	force coefficient: us indalone silos, "row o
Wind force coefficient	Standard	✓ → groups/rows o	vessels, or input

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.

11.2.6. Seismic

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.

Seismic (according EN 1998-1 and EN 1998-4)				
More info				
Horizontal design acceleration, plateau area	S _d (T ₁)	0	m/s ²	

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.

11.3. 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'.



11.3.1. 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 A3-factor).

Address the A2-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.

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.

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

11.3.2. Cover

0.....

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 rei	nforcement
Crown (Tb)	0	0.0	mm		
Knuckle (Tk)	0	0.0	mm	0	mm



11.3.3. 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	
Cylinder	0	0.0	mm
Ring	0	0.0	mm





12. Ply Based Engineering

12.1. Concept

Instead of relying on a single winding material, users can now specify a **base material**, which acts as the structural liner or mold with an initial thickness, and a **layer material**, which is wound over the base to form the composite structure. This dual-material approach enhances modeling accuracy, particularly for designs that incorporate a permanent liner or require different mechanical properties between the base and the outer layers.



12.2. Feature

Feature that allows users to define two distinct materials in the design of composite storage vessels manufactured by filament winding.

Cylinder

Length of cylinder	Lc 8500	mm		
Diameter	D 2500	mm		з
Volume	VI 67	m ³		
Cylinder material	Winding Material	~	D	,
Separate cylinder base layer	No	~		



Cylinder

Length of cylinder	Lc 8500	mm
Diameter	D 2500	mm
Volume	VI 67	m ³
Cylinder material	Winding Material	~
Cylinder material base layer	Spray Material	~
Separate cylinder base layer	Yes	~



Base material: Structural liner or mold with an initial thickness

Layer material: Wound over the base to form the composite structure.

This feature can be used on the following components (All vessel types):

- Cover
- Cylinder
- Bottoms
- Support

12.3. Material definition

Base layer takes the Pre-Run laminate thickness one time

Layer material takes the module thickness N times.



13. 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

13.1. 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 \geq 1 always in red.

13.2. 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. Please note that we now provide a general table on the downloadable report.



13.2.1.1. General Tables

13.2.1.2. Vertical Tank

These are examples and the table depends on the geometries chosen during the analysis

Part		Thickness [mm]	Material	
Cover crown $t_{\scriptscriptstyle b}$		4.4	Spray Material (4 modules)	
Cover knuckle $t_{\scriptscriptstyle bk}$		4.4	Spray Material (4 modules) (Length (105 mm)	
$\begin{array}{c} \text{Cylinder} & 8 \rightarrow 8.5 \\ t_s & \text{m} \end{array}$		3.3	Winding Material (3 modules)	
	$7 \rightarrow 8 \text{ m}$	3.3	Winding Material (3 modules)	
	$6 \rightarrow 7 \text{ m}$	4.4	Winding Material (4 modules)	
	$5 \rightarrow 6 \text{ m}$	4.4	Winding Material (4 modules)	
	$4 \rightarrow 5 \text{ m}$	5.5	Winding Material (5 modules)	
	$3 \rightarrow 4 \text{ m}$	6.6	Winding Material (6 modules)	
	$2 \rightarrow 3 \text{ m}$	7.7	Winding Material (7 modules)	
	$1 \rightarrow 2 \text{ m}$	8.8	Winding Material (8 modules)	
	$0 \rightarrow 1 \text{ m}$	9.9	Winding Material (9 modules)	
Bottom $t_{\scriptscriptstyle b}$		7.7	Winding Material (7 modules)	
Bottom t_{*}		45.1	Winding Material(41 modules) (Length : 186 mm)	
Bottom $t_{\scriptscriptstyle ex}$		30.8	Winding Material(28 modules) (Length : 277 mm)	
Support t _z		30.8	Heterogeneous material. Base: Spray Material; Modules: Winding Material(28 modules) (Length : 277 mm)	
Support $t_{\rm sku}$		18	Heterogeneous material. Base: Spray Material; Modules: Winding Material(16 modules) (Length : 212 mm)	
Support t_{sk}		11.4	Heterogeneous material. Base: Spray Material; Modules: Winding Material(10 modules) (Length : 2500 mm)	



13.2.1.3. <u>Silo</u>

Part		Thickness [mm]	Material	
Cover crown t_b		4	M3 - ABZ_Z-40.17-44 (4 modules)	
Cover knuckle t _{bk}		4	M3 - ABZ_Z-40.17-44 (4 modules) (Length (100 mm)	
$\begin{array}{c} \text{Cylinder} & 8 \rightarrow 9 \\ t_z & \text{m} \end{array}$		3.7	Heterogeneous material. Base: Spray Material; Modules: Winding Material (3 modules)	
	7 → 8 m	4.8	Heterogeneous material. Base: Spray Material; Modules: Winding Material (4 modules)	
	6 → 7 m	5.9	Heterogeneous material. Base: Spray Material; Modules: Winding Material (5 modules)	
	5 → 6 m	7	Heterogeneous material. Base: Spray Material; Modules: Winding Material (6 modules)	
	4 → 5 m	8.1	Heterogeneous material. Base: Spray Material; Modules: Winding Material (7 modules)	
	3 → 4 m	9.2	Heterogeneous material. Base: Spray Material; Modules: Winding Material (8 modules)	
	2 → 3 m	10.3	Heterogeneous material. Base: Spray Material; Modules: Winding Material (9 modules)	
	1 → 2 m	10.3	Heterogeneous material. Base: Spray Material; Modules: Winding Material (9 modules)	
	0 → 1 m	11.4	Heterogeneous material. Base: Spray Material; Modules: Winding Material (10 modules)	
Bottom t _b		4.8	Heterogeneous material. Base: Spray Material; Modules: Winding Material (4 modules)	
Bottom t _k		8.1	Heterogeneous material. Base: Spray Material; Modules: Winding Material(7 modules) (Length : 500 mm)	
Bottom t_e		14.7	Heterogeneous material. Base: Spray Material; Modules: Winding Material(13 modules) (Length : 198 mm)	
Bottom t_{ez}		11.4	Heterogeneous material. Base: Spray Material; Modules: Winding Material(10 modules) (Length : 169 mm)	
Support t _z		11.4	Winding Material(10 modules) (Length : 169 mm)	
Support t _{abs}		11	Winding Material(10 modules) (Length : 166 mm)	
Support t _{sk}		11	Winding Material(10 modules) (Length : 2500 mm)	



13.2.1.4. Horizontal Tanks (Rib Stiffened)

Part	Thickness [mm]	Material
Cover crown $t_{\rm b}$	3.4	Heterogeneous material. Base: Spray Material; Modules: Spray Material(3 modules)
Cover knuckle t _{lik}	5.4	Heterogeneous material. Base: Spray Material; Modules: Spray Material(5 modules) (Length: 96 mm)
Cylinder t_z	0.4	Heterogeneous material. Base: Spray Material; Modules: Winding Material(0 modules)
Ring t_r	0	Winding Material (0 modules) (Ring width: 400)

13.3. Materials

• These are examples only for the cylinder and cover, and it depends on the geometries chosen during the analysis.

2. Characteristic values

2.1 Material properties

2.1.1 Resin properties:

Name	Туре	HDT
Resin1	Orthophtalic polyester	73.0°

Material properties:

2.1.2 Cover

	Laminate		
ρ [kg/m³]	1520		
	Circumferential	Axial	
E [MPa]	7300	7300	
σ _t [MPa]	85	85	

2.1.3 Cylinder

	Base material		Layered material	
ρ [kg/m ³]	1520		1520	
	Circumferential	Axial	Circumferential	Axial
E [MPa]	7300	7300	7970	6666
σ _t [MPa]	85	85	118	67