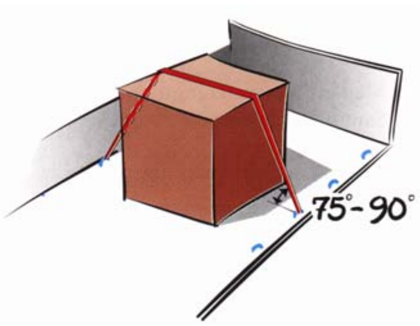
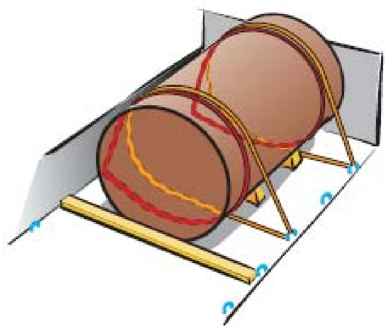
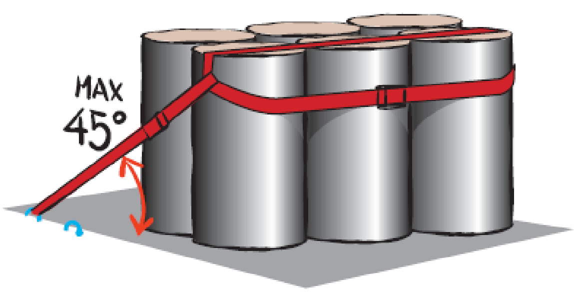
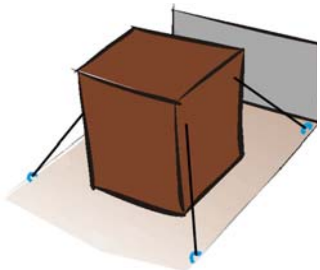
Formulas used in the Caring Cargo Calculator

	
Top-over lashing	Loop lashing
	
Spring lashing	Straight/cross lashing

Version 2013-08-23

Education and Culture DG
Lifelong Learning Programme

Table of contents

Education and Culture DG
Lifelong Learning Programme

1 Parameters in the Formulas

General parameters		***Unit***
f_s =	Safety factor for frictional lashings	-
m =	Mass of the load	ton (=1000 kg)
N =	Number of rows	-
n =	Number of lashing	-
Accelerations		
g =	Gravitational acceleration (= 9.81 m/s^2)	m/s^2
c_x =	Longitudinal acceleration	-
c_y =	Transverse acceleration	-
c_z =	Vertical acceleration	-
Friction		
μ =	Friction factor	-
f_μ =	Conversion factor for dynamic friction	-
Properties of the lashing device		
FT =	Tension force of a lashing device (= STF)	kN (= 100 daN)
S_{TF}=	Standard tension force	kN (= 100 daN)
FR=	Restraining force of a lashing device	kN (= 100 daN)
LC =	Lashing capacity of a lashing device	kN (= 100 daN)
Angles		
α =	Vertical lashing angle	°
βx=	Longitudinal lashing angle	°
βy=	Transverse lashing angle	°
α =	Vertical lashing angle	°

Distances		***Unit***
L =	Total length of the cargo	m

B =	Total width (breadth) of the cargo	m
H =	Total height of the cargo	m
w =	Width of the load	m
h =	Lever arm lashing moment	m
$b = B_{tp}$ =	Transverse distance from the centre of gravity of the load to tipping point (lever arm of standing moment)	m
$b = L_{tp}$ =	Longitudinal distance from the centre of gravity of the load to the tipping point (lever arm of standing moment)	m
$d = H_{tp}$ =	Vertical distance from the centre of gravity of the load to the tipping point (lever arm of tilting moment)	m
l =	Distance between the lashing point of the cargo and the point of tipping of the cargo in longitudinally direction (laver arm of the lashing moment)	m
s =	Vertical distance from the platform to the point where the lashing device acts on the load	m
t =	Vertical distance from platform to the tipping point	m
p =	Vertical distance from the outer edge of the load to the point where the lashing device acts on the load	m
r =	Horizontal distance from the outer edge of the load to the tipping point	m

Note:

- If **m < 0** in any of the formulas there is no risk of sliding or tipping
- *LC* = *MSL* = *SWL* = Lashing capacity

2 TOP-OVER LASHING

2.1 EN 12195-1:2010

2.1.1 Sliding:

Basic formula according EN12195-1:2010

All Directions

$$n \geq \frac{m \cdot g(c_{x,y} - c_z \cdot \mu)}{2\mu \cdot \sin\alpha \cdot F_T} \cdot f_s \qquad \textit{Equ (10)}$$

with n = 1 the following formula is given for the mass m one top-over lashing can prevent from sliding in all direction:

All directions:

$$m = \frac{2\mu \cdot \sin\alpha \cdot F_T}{g(c_{x,y} - \mu \cdot c_Z)\, f_s}$$

In the cargo calculator the following values are used;

m =	Mass of the load in tons
μ =	Friction factor which is a key value in the tables
f_s =	Safety factor; 1.25 (forward on road) else 1.1
F_T =	Tension force of lashing device in kN (Note: 1 kN = 100 daN)
α =	75º
$c_{x,y,z}$ =	Due to mode of transport according to table *2, 3* and *4* in standard
g =	9.81 m/s^2

2.1.2 Tipping:

Basic formula according to EN12195-1:2010

For-and rearward $$2n \cdot F_T \cdot \sin\alpha \cdot \frac{L}{2} \geq m \cdot g(c_x \cdot d - c_z \cdot b) \cdot f_s$$ *Equ (15)*

Transvers $$n \geq \frac{m \cdot g(c_y \cdot d - c_z \cdot b)}{w \cdot F_T(\sin\alpha + 0.25 \cdot (N-1)} \cdot f_s$$ *Equ (16)*

Forward, rearward:

with n = 1, $d = H_{tp}$, and $b = L_{tp}$ the following formula is given for the mass m one top-over lashing can prevent from lengthways tipping:

$$m = \frac{F_T \cdot \sin\alpha \cdot L}{g(c_x \cdot H_{tp} - c_z \cdot L_{tp}) \cdot f_s}$$

In case of symmetrical mass centre of the cargo;

$H_{tp} = \frac{H}{2}, L_{tp} = \frac{L}{2}$ and n = 1:

$$m = \frac{2 \cdot F_T \cdot \sin\alpha}{g(c_x \cdot \frac{H}{L} - c_z) \cdot f_s}$$

Transvers, 1 row:

with n = 1, $N = 1$, $w = B$, $d = H_{tp}$, and $b = B_{tp}$ the following formula is given for the mass m one top-over lashing can prevent from lengthways tipping:

$$m = \frac{F_T \cdot \sin\alpha \cdot B}{g(c_y \cdot H_{tp} - c_z \cdot B_{tp}) \cdot f_s}$$

In case of symmetrical mass centre of the cargo;

$H_{tp} = \frac{H}{2}, B_{tp} = \frac{B}{2}$ and n = 1:

$$m = \frac{2 \cdot F_T \cdot \sin\alpha}{g(c_y \cdot \frac{H}{B} - c_z) \cdot f_s}$$ *Equ (14)*

Transverse, several rows, in case of symmetrical mass centre of the cargo;

$H_{tp} = \frac{H}{2}$, $B_{tp} = \frac{B}{2}$ and n = 1:

$$m = \frac{2 \cdot F_T \cdot (\sin\alpha + 0.25 \cdot (N-1))}{g(c_y \cdot N \cdot \frac{H}{B} - c_z) \cdot f_s} \qquad \textit{Equ (17)}$$

In the cargo calculator the following values are used;

m =	Mass of the load in tons
H/L =	The ratio height *H* and length *L* which is a key value in the tables in *forward* and *backward* direction
H/B =	The ratio height *H* and width *B* which is a key value in the tables in *transverse* direction
F_T =	Tension force of lashing device in kN (if a_h = 0.5) or *LC*/2 (if a_h = 0.6). (Note 1 kN = 100 daN)
α =	75º
f_s =	Safety factor; 1.25 (forward on road) else 1.1
$c_{x,y,z}$ =	Due to mode of transport according to table 2, 3 and 4 in standard
N =	Number of rows which is a key value in tables for transverse direction
g =	9.81 m/s^2

Note!

The risk of tilting is calculated with c_y = 0.5 and F_T = tension force in the lashing device. When there is risk of tilting the lowest value of the two alternatives, c_y = 0.5 and F_T or c_y = 0.6 and *LC*/2, is presented by the cargo calculator.

3 LOOP LASHING

3.1 EN 12195-1:2010

3.1.1 Sliding:

Basic formula according to EN 12195-1:2010

$$n \geq \frac{m \cdot g(c_y - c_z \cdot f_\mu \cdot \mu)}{F_R(\cos\alpha_1 \cdot \sin\beta_{x_1} + \cos\alpha_2 \cdot \sin\beta_{x_2} + f_\mu \cdot \mu \cdot \sin\alpha_1 + f_\mu \cdot \mu \cdot \sin\alpha_2)} \qquad \textit{Equ (30)}$$

with $F_R = LC$, $\mu_d = f_\mu \cdot \mu$, $\alpha_2 = 0º$, β_{x1} and $\beta_{x2} = 90º$ the following formula is given for the mass *m* one pair of loop lashing can prevent from sliding in transverse direction:

Transverse:

$$m = \frac{LC \cdot (\mu \cdot f_\mu \cdot \sin\alpha_1 + 1 + \cos\alpha_1)}{(c_y - \mu \cdot f_\mu \cdot c_z) \cdot g}$$

In the cargo calculator the following values are used;

m =	Mass of the load in tons
μ =	Friction factor which is a key value in the tables
f_μ =	0.75
LC =	Lashing capacity of lashing device in kN (Note: 1 kN = 100 daN)
α_1 =	90º
$c_{y,z}$ =	Due to mode of transport according to table *2, 3* and *4* in standard
g =	9.81 m/s^2

3.1.2 Tipping:

Basic formula according to EN 12195-1:2010

$$n \geq \frac{m \cdot g(c_y \cdot d - c_z \cdot b)}{F_R(\sin\alpha_1 \cdot w + \cos\alpha_1 \cdot \sin\beta_{x1} \cdot h + 0.25(N-1) \cdot w)} \qquad \text{Equ (33)}$$

In case of symmetrical mass centre of the cargo;

d = $H_{tp} = \frac{H}{2}$, *b* = $B_{tp} = \frac{B}{2}$, *w* = *B*, *n* = 1, α_1 = 90º and β_{x1} = 90º

gives the following formula for the mass m one pair of loop lashing can prevent from tipping in transverse direction:

Transverse:

$$m = \frac{2 \cdot F_R \cdot (1 + (N-1) \cdot 0.25)}{(c_y \cdot N \cdot \frac{H}{B} - c_z) \cdot g}$$

In the cargo calculator the following values are used;

m =	Mass of the load in tons
H/B =	The ratio height *H* and width *B* which is a key value in the tables in *transverse* direction
F_R =	0.5 ·LC
LC =	Lashing capacity of lashing device in kN (Note: 1 kN = 100 daN)
$c_{y,z}$ =	Due to mode of transport according to table *2, 3* and *4* in standard
N =	Number of rows which is a key value in tables for transverse direction
g =	9.81 m/s^2

4 SPRING LASHING

4.1 EN 12195-1:2010

4.1.1 Sliding:

Basic formula according to EN 12195-1:2010

$$n \geq \frac{m \cdot g(c_x - c_z \cdot f_\mu \cdot \mu)}{F_R(\mu \cdot f_\mu \cdot \sin\alpha + \cos\alpha \cdot \cos\beta_{x,y})}$$ *Based on Equ (35)*

with $F_R = LC$, $\beta_{x,y} = 0º$ and $n = 2$ (spring lashing with two parts) the following formula is given for the mass *m* one spring lashing can prevent from sliding in lengthways direction

Forward, rearward: $$m = \frac{2 \cdot LC \cdot (\mu \cdot f_\mu \cdot \sin\alpha_1 + \cos\alpha_1)}{(c_x - \mu \cdot f_\mu \cdot c_z) \cdot g}$$

In the cargo calculator the following values are used;

m =	Mass of the load in tons
μ =	Friction factor which is a key value in the tables
f_μ =	0.75
LC =	Lashing capacity of lashing device in kN (Note: 1 kN = 100 daN)
α_1 =	45º
$c_{x,z}$ =	Due to mode of transport according to table *2, 3* and *4* in standard
g =	9.81 m/s^2

4.1.2 Tipping:

Basic formula according to EN 12195-1:2010

$$n \geq \frac{m \cdot g(c_x \cdot d - c_z \cdot b)}{F_R \cdot 2(\cos\alpha \cdot \cos\beta_{x,y} \cdot (s-t) + \sin\alpha \cdot (p-r))}$$ *Based on Equ (37)*

with $F_R = LC$, $\beta_{x,y} = 0º$, $d = H_{tp}$, $b = L_{tp}$, $(s-t) = H$, and $(p-r) = 0$ gives the following formula for the mass *m* one spring lashing can prevent from tipping in lengthways direction:

Forward, rearward:

$$m = \frac{2 \cdot LC \cdot \cos\alpha \cdot H}{(c_x \cdot H_{tp} - c_z \cdot L_{tp}) \cdot g}$$

In case of symmetrical mass centre of the cargo;

$$H_{tp} = \frac{H}{2},\ L_{tp} = \frac{L}{2}:$$

$$m = \frac{4 \cdot LC \cdot \cos\alpha \cdot \frac{H}{L}}{(c_x \cdot \frac{H}{L} - c_z) \cdot g}$$

In the cargo calculator the following values are used;

m =	Mass of the load in tons
H/L =	The ratio height *H* and length *L* which is a key value in the tables in *forward* and *backward* direction
LC =	Lashing capacity of lashing device in kN (Note: 1 kN = 100 daN)
α =	45º
$C_{x,z}$=	Due to mode of transport according to table *2, 3* and *4* in standard
g =	9.81 m/s^2

5 STRAIGHT/CROSS LASHING

5.1 *EN 12195-1:2010*

5.1.1 Sliding:

Basic formula according to EN 12195-1:2010

Forward, rearward: $$n \geq \frac{m \cdot g(c_x - c_z \cdot f_\mu \cdot \mu)}{F_R(f_\mu \cdot \mu \cdot \sin\alpha + \cos\alpha \cdot \cos\beta_y)}$$ *Based on Equ (22)*

Transverse: $$n \geq \frac{m \cdot g(c_y - c_z \cdot f_\mu \cdot \mu)}{F_R(f_\mu \cdot \mu \cdot \sin\alpha + \cos\alpha \cdot \cos\beta_x)}$$ *Based on Equ (22)*

with $F_R = LC$ and $n = 1$ the following formulas are given for the mass *m* one straight/cross lashing can prevent from sliding in different direction

Forward: $$m = \frac{LC \cdot (\cos\alpha \cdot \cos\beta_y + \mu \cdot f_\mu \cdot \sin\alpha)}{(c_x - \mu \cdot f_\mu \cdot c_z) \cdot g}$$

Transverse: $$m = \frac{LC \cdot (\cos\alpha \cdot \cos\beta_x + \mu \cdot f_\mu \cdot \sin\alpha)}{(c_y - \mu \cdot f_\mu \cdot c_z) \cdot g}$$

Backward: $$m = \frac{LC \cdot (\cos\alpha \cdot \cos\beta_y + \mu \cdot f_\mu \cdot \sin\alpha)}{(c_x - \mu \cdot f_\mu \cdot c_z) \cdot g}$$

In the cargo calculator the following values are used;

m =	Mass of the load in tons
μ =	Friction factor which is a key value in the tables
f_μ =	0.75
LC =	Lashing capacity of lashing device in kN (Note: 1 kN = 100 daN)
α =	60º, β_x = 30º, β_y = *30º*
$c_{x,y,z}$=	Due to mode of transport according to table *2, 3* and *4* in standard
g =	9.81 m/s^2

5.1.2 Tipping:

Basic formula according to EN 12195-1:2010

Forward, rearward: $$n \geq \frac{m \cdot g(c_x \cdot d - c_z \cdot b)}{F_R \cdot (\cos\alpha \cdot \cos\beta_y \cdot (s-t) + \sin\alpha \cdot (p-r))}$$

Transverse: $$n \geq \frac{m \cdot g(c_y \cdot d - c_z \cdot b)}{F_R \cdot 2(\cos\alpha \cdot \cos\beta_x \cdot (s-t) + \sin\alpha \cdot (p-r))}$$

with $F_R = LC$, $d = H_{tp}$, $b = L_{tp}$ and $n = 1$ the following formulas are given for the mass *m* one straight/cross lashing can prevent from tipping in different direction:

Forward: $$m = \frac{LC \cdot (\cos\alpha \cdot \cos\beta_y \cdot (s-t) + \sin\alpha \cdot (p-r))}{c_x \cdot H_{tp} - c_z \cdot L_{tp}}$$

Transverse: $$m = \frac{LC \cdot (\cos\alpha \cdot \cos\beta_x \cdot (s-t) + \sin\alpha \cdot (p-r))}{c_y \cdot H_{tp} - c_z \cdot B_{tp}}$$

Backward: $$m = \frac{LC \cdot (\cos\alpha \cdot \cos\beta_y \cdot (s-t) + \sin\alpha \cdot (p-r))}{c_x \cdot H_{tp} - c_z \cdot L_{tp}}$$

In case of symmetrical mass centre of the cargo and the lashing point is placed in an unfavourable position;

$$H_{tp} = \frac{H}{2};\ L_{tp} = \frac{L}{2};\ B_{tp} = \frac{B}{2};\ (s-t) = \frac{H}{2} + \frac{B}{2}\ or\ h = \frac{H}{2} + \frac{L}{2};\ (p-r) = 0$$

Forward:

$$m = \frac{LC \cdot (\cos\alpha \cdot \cos\beta_y \cdot (\frac{H}{L} + 1))}{(c_x \cdot \frac{H}{L} - c_z) \cdot g}$$

Transverse:

$$m = \frac{LC \cdot (\cos\alpha \cdot \cos\beta_x \cdot (\frac{H}{B} + 1)}{(c_y \cdot \frac{H}{B} - c_z) \cdot g}$$

Backward:

$$m = \frac{LC \cdot (\cos\alpha \cdot \cos\beta_y \cdot (\frac{H}{L} + 1))}{(c_x \cdot \frac{H}{L} - c_z) \cdot g}$$

In the cargo calculator the following values are used;

m =	Mass of the load in tons
H/L =	The ratio height H and length L which is a key value in the tables in forward and backward direction
H/B =	The ratio height H and width B which is a key value in the tables in transverse direction
LC =	Lashing capacity of lashing device in kN (Note: 1 kN = 100 daN)
α =	30º
β_x =	30º
β_y =	30º
$c_{x,y,z}$=	Due to mode of transport according to table 2, 3 and 4 in standard
g =	9.81 m/s^2