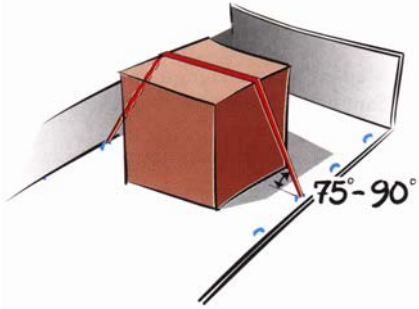
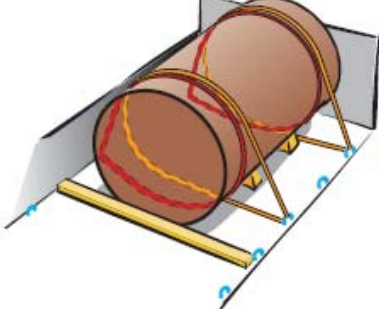
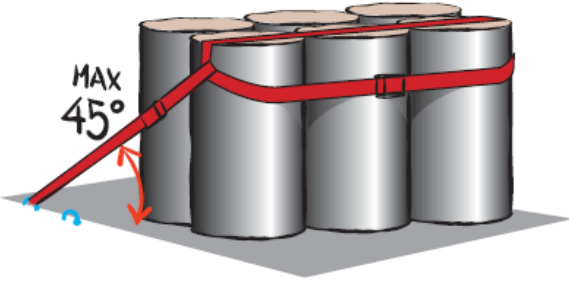
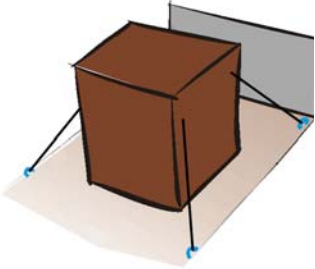


# Formulas used in the Caring Cargo Calculator

 <p>75-90°</p>	
Top-over lashing	Loop lashing
 <p>MAX 45°</p>	
Spring lashing	Straight/cross lashing

Version 2013-08-23

## Table of contents

	<i>Page</i>
Table of contents.....	1
1 Parameters in the Formulas.....	2
2 TOP-OVER LASHING.....	4
2.1 EN 12195-1:2010 .....	4
2.1.1 Sliding:.....	4
2.1.2 Tipping:.....	5
3 LOOP LASHING .....	7
3.1 EN 12195-1:2010 .....	7
3.1.1 Sliding:.....	7
3.1.2 Tipping:.....	8
4 SPRING LASHING .....	9
4.1 EN 12195-1:2010 .....	9
4.1.1 Sliding:.....	9
4.1.2 Tipping:.....	10
5 STRAIGHT/CROSS LASHING .....	11
5.1 EN 12195-1:2010 .....	11
5.1.1 Sliding:.....	11
5.1.2 Tipping:.....	12

# 1 Parameters in the Formulas

## **General parameters**

		<b>Unit</b>
$f_s =$	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 <sup>2</sup> )	m/s <sup>2</sup>
$c_x =$	Longitudinal acceleration	-
$c_y =$	Transverse acceleration	-
$c_z =$	Vertical acceleration	-

## **Friction**

$\mu =$	Friction factor	-
$f_\mu =$	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**

$\alpha =$	Vertical lashing angle	°
$\beta_x =$	Longitudinal lashing angle	°
$\beta_y =$	Transverse lashing angle	°
$\alpha =$	Vertical lashing angle	°

## **Distances**

		<b>Unit</b>
$L =$	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

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

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

$$\text{All directions:} \quad m = \frac{2\mu \cdot \sin \alpha \cdot F_T}{g(c_{x,y} - \mu \cdot c_z) f_s}$$

In the cargo calculator the following values are used;

$m =$	Mass of the load in tons
$\mu =$	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)
$\alpha =$	75°
$c_{x,y,z} =$	Due to mode of transport according to table 2, 3 and 4 in standard
$g =$	9.81 m/s <sup>2</sup>

## 2.1.2 Tipping:

### Basic formula according to EN12195-1:2010

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

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

### 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;

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

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

### 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;

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

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

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

$$H_p = \frac{H}{2}, B_p = \frac{B}{2} \text{ and } n = 1:$$

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

**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 <i>forward</i> and <i>backward</i> direction
$H/B =$	The ratio height $H$ and width $B$ which is a key value in the tables in <i>transverse</i> 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)
$\alpha =$	75°
$f_s =$	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 <sup>2</sup>

**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

$$n \geq \frac{m \cdot g (c_y - c_z \cdot f_\mu \cdot \mu)}{F_R (\cos \alpha_1 \cdot \sin \beta_{x1} + \cos \alpha_2 \cdot \sin \beta_{x2} + f_\mu \cdot \mu \cdot \sin \alpha_1 + f_\mu \cdot \mu \cdot \sin \alpha_2)} \quad \text{Equ (30)}$$

with  $F_R = LC$ ,  $\mu_d = f_\mu \cdot \mu$ ,  $\alpha_2 = 0^\circ$ ,  $\beta_{x1}$  and  $\beta_{x2} = 90^\circ$  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
$\mu =$	Friction factor which is a key value in the tables
$f_\mu =$	0.75
$LC =$	Lashing capacity of lashing device in kN (Note: 1 kN = 100 daN)
$\alpha_1 =$	$90^\circ$
$c_{y,z} =$	Due to mode of transport according to table 2, 3 and 4 in standard
$g =$	$9.81 \text{ m/s}^2$



### 3.1.2 Tipping:

#### Basic formula according to EN 12195-1:2010

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

In case of symmetrical mass centre of the cargo;

$$d = H_{tp} = \frac{H}{2}, b = B_{tp} = \frac{B}{2}, w = B, n = 1, \alpha_1 = 90^\circ \text{ and } \beta_{x1} = 90^\circ$$

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 <i>transverse</i> direction
$F_R =$	$0.5 \cdot LC$
$LC =$	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
$g =$	$9.81 \text{ m/s}^2$

## 4 SPRING LASHING

### 4.1 EN 12195-1:2010

#### 4.1.1 Sliding:

Basic formula according to EN 12195-1:2010

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

with  $F_R = LC$ ,  $\beta_{x,y} = 0^\circ$  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
$\mu =$	Friction factor which is a key value in the tables
$f_\mu =$	0.75
$LC =$	Lashing capacity of lashing device in kN (Note: 1 kN = 100 daN)
$\alpha_1 =$	45°
$c_{x,z} =$	Due to mode of transport according to table 2, 3 and 4 in standard
$g =$	9.81 m/s <sup>2</sup>

## 4.1.2 Tipping:

### Basic formula according to EN 12195-1:2010

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

with  $F_R = LC$ ,  $\beta_{x,y} = 0^\circ$ ,  $d = H_{tp}$ ,  $b = L_{tp}$ ,  $(s-t) = H$ , 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;

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

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

**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 <i>forward</i> and <i>backward</i> direction
$LC =$	Lashing capacity of lashing device in kN (Note: 1 kN = 100 daN)
$\alpha =$	45°
$C_{x,z} =$	Due to mode of transport according to table 2, 3 and 4 in standard
$g =$	9.81 m/s <sup>2</sup>

## 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
$\mu =$	Friction factor which is a key value in the tables
$f_\mu =$	0.75
$LC =$	Lashing capacity of lashing device in kN (Note: 1 kN = 100 daN)
$\alpha =$	$60^\circ$ , $\beta_x = 30^\circ$ , $\beta_y = 30^\circ$
$c_{x,y,z} =$	Due to mode of transport according to table 2, 3 and 4 in standard
$g =$	$9.81 \text{ m/s}^2$

## 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;

$$H_p = \frac{H}{2}; L_p = \frac{L}{2}; B_p = \frac{B}{2}; (s-t) = \frac{H}{2} + \frac{B}{2} \text{ or } h = \frac{H}{2} + \frac{L}{2}; (p-r) = 0$$

**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)
$\alpha =$	30°
$\beta_x =$	30°
$\beta_y =$	30°
$c_{x,y,z} =$	Due to mode of transport according to table 2, 3 and 4 in standard
$g =$	9.81 m/s <sup>2</sup>