Strength and efficiency of Cordstrap QuickLash® SD and SD-R solutions

Appendix CS2020010A
to MariTerm AB Certificate CS2020010

Single and double Cordstrap QuickLash® SD & SD-R solutions in 20ft CTUs

Double Cordstrap QuickLash® SD & SD-R solutions in a 40ft CTU

Content

Preamble

MariTerm AB has on behalf of Cordstrap BV evaluated the strength and efficiency of the Cordstrap QuickLash® SD and SD-R solutions for securing of cargoes in freight containers. In addition MariTerm AB has developed an Excel tool for generating tables for Quick Lashing Guides for these lashing solutions.

In this report, the theoretical background for the calculations of lashing forces as well as lashing tables for different modes of transport are given. The calculations are performed for 20ft and 40ft CTUs with two different strengths in the anchor points; 1000 daN and 2000 daN.

The calculations in this document complies with the principles in the IMO/ILO/UNECE Code of Practice for Packing of Cargo Transport Units (CTU Code)

According to the CTU Code, "the doors may be considered as a strong cargo space boundary, provided the cargo is stowed to avoid impact loads to the door end and to prevent the cargo from falling out when the doors are opened". The sum of void spaces in any horizontal direction should not exceed 15 cm.

Solution Elements Specifications

Cordstrap QuickLash® SD and SD-R Vertical Lashings (1 per side)

Linear Breaking Strength	.
Elongation at LC	<7% (EN 12195-2)
Width	32 mm / 1.1/4"
Thickness	1.5 mm / 1/16"
Material	High tenacity polyester filament yarn
The vertical lashing is applied in a full loop around two snaphooks at both ends. The SnapHooks have a breaking strength of 4000 daN.	

Cordstrap QuickLash® SD and SD-R Horizontal Lashings (4 per side)

Linear Breaking Strength	2 300 daN / 5 060 lbf
Elongation at LC	<7% (EN 12195-2)
Width	32 mm / 1.1/4"
Thickness	1.5 mm / 1/16"
Material	High tenacity polyester filament yarn
The horizontal lashing is applied around the vertical lashing with a loop at the end.	
Buckle Specifications	
Breaking Strength	6 000 daN / 13 200 lbf
Width	35 mm / 1.1/4"
Material	Galvanized dropforged steel
Pieces required per solution	4

A Cordstrap QuickLash® SD-R solution is exactly the same as SD, but it has a strong elastic band stitched to each horizontal lashing. This elastic band is not an active part of the securing arrangement. It is a means to keep the horizontal lashing in position in case of cargo compression in the direction away from the container doors: it can compensate for up to 20 cm load compression and assure the lashing will remain in place.

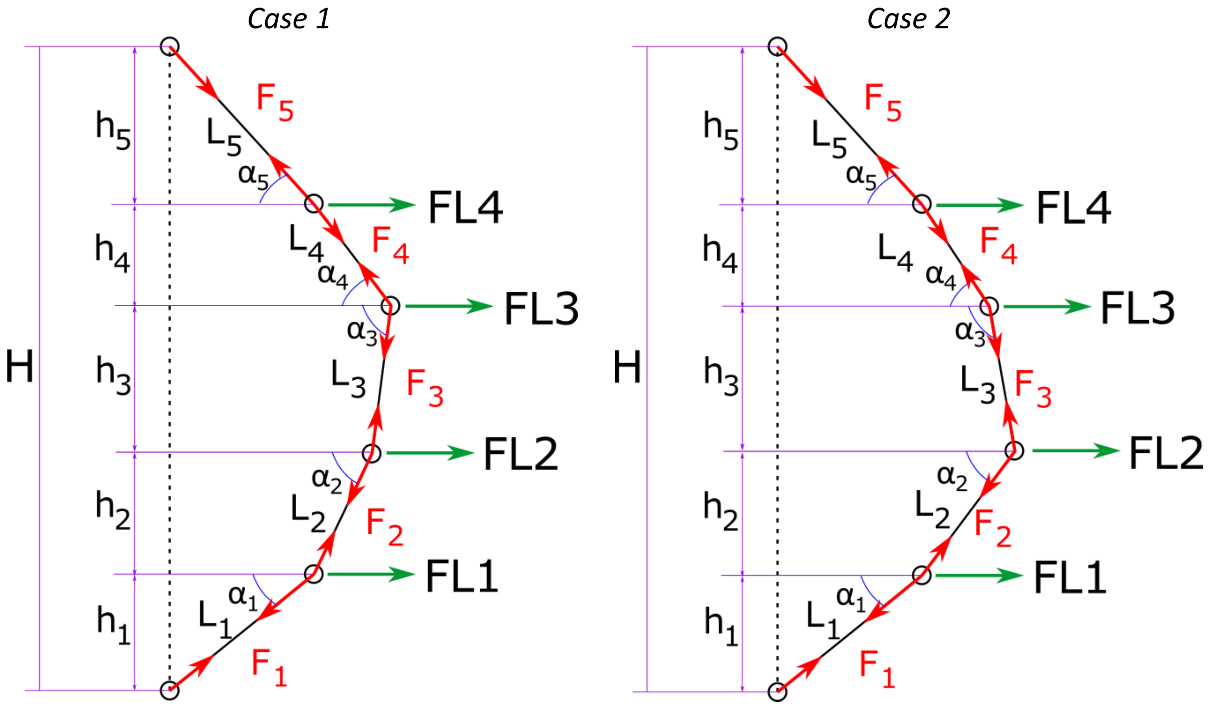
A single Cordstrap QuickLash® SD and SD-R solution consists of 2 sides, made out of 1 Vertical Lashing and 4 Horizontal Lashings each, , and 4 buckles.

A double Cordstrap QuickLash® SD & SD-R solution consists of 4 sides, made out of 1 Vertical Lashing and 4 Horizontal Lashings each, and 8 buckles on total.

In the calculations in this document it is assumed that the goods are rigid. For non-rigid goods i.e. carton boxes, plastic drums, big bags or small bags on pallets, the SD-R solution is used with advantage.

Theoretical lashing forces – Cordstrap QuickLash® SD & SD-R solution

The principal forces acting in the lashings, on the lashing/anchor points and on the cargo is presented in the figures below.



Forces in a single Cordstrap QuickLash® SD & SD-R solution, for two different cases

The construction of Cordstrap QuickLash SD & SD-R solutions is such that the distance between the lowest and highest lashing is a fixed length. This means that $L_2+L_3+L_4$ is equal to a constant, in this case 126 cm. Since the total length of the vertical lashing is also given, L_1+L_5 is a constant as well, in this case 152 cm.

The following formulas are set up to calculate the different angles and forces maximally leveraging the strength of the container securing points:

Balance of forces – Horizontal
$FL1 = F_1 * \cos(\alpha_1) - F_2 * \cos(\alpha_2)$
Case 1: $FL2 = F_2 * \cos(\alpha_2) - F_3 * \cos\ (\alpha_3)$
Case 2: $FL2 = F_2 * \cos(\alpha_2) + F_3 * \cos(\alpha_3)$
Case 1: $FL3 = F_3 * \cos(\alpha_3) + F_4 * \cos\ (\alpha_4)$
Case 1: $FL3 = -\ F_3 * \cos(\alpha_3) + F_4 * \cos\ (\alpha_4)$
$FL4 = F_5 * \cos(\alpha_5) - F_4 * \cos(\alpha_4)$

Balance of forces – Vertical
$F_1 * \sin(\alpha_1) = F_2 * \sin(\alpha_2)$
$F_2 * \sin(\alpha_2) = F_3 * \sin(\alpha_3)$
$F_3 * \sin(\alpha_3) = F_4 * \sin(\alpha_4)$
$F_4 * \sin(\alpha_4) = F_5 * \sin(\alpha_5)$

Geometry balance – Horizontal
Case 1: $L_1 * \cos(\alpha_1) + L_2 * \cos(\alpha_2) + L_3 * \cos(\alpha_3) - L_4 * \cos(\alpha_4) - L_5 * \cos(\alpha_5) = 0$
Case 2: $L_1 * \cos(\alpha_1) + L_2 * \cos(\alpha_2) - L_3 * \cos(\alpha_3) - L_4 * \cos(\alpha_4) - L_5 * \cos(\alpha_5) = 0$

Geometry balance – Vertical
$L_1 * \sin(\alpha_1) + L_2 * \sin(\alpha_2) + L_3 * \sin(\alpha_3) + L_4 * \sin(\alpha_4) + L_5 * \sin(\alpha_5) = H$

$F_1 = MIN(MSL_{anchor\ point}\ ; 2 \times\ MSL_{vertical\ lashing})$

$F_5 = MIN(MSL_{top\ lashing\ point}\ ;\ 2 \times\ MSL_{\ vertical\ lashing})$

Where

$MSL_{vertical\ lashing}$	MSL in Vertical lashing (in daN)
$MSL_{horizontal\ lashing}$	MSL in Horizontal lashing (in daN)
$MSL_{anchor\ point}$	MSL in container bottom anchor points (in daN)
$MSL_{top\ lashing\ point}$	MSL in container top lashing points (in daN)

Forces and angles

F	Force in the vertical lashings (system loop) in daN
FL	Force in the horizontal lashings (single part) in daN

$MSL_{vertical\ lashing}$	Maximum securing load of vertical lashings (system loop with snaphook) = 2000 daN
$MSL_{horizontal\ lashing}$	Maximum securing load of horizontal lashings (single part) = 1125 daN

CTU with normal strength lashing points:

$MSL_{anchor\ point}$	Maximum securing load of container anchor point = 1000 daN
$MSL_{top\ lashing\ point}$	Maximum securing load of container roof lashing point = 500 daN

CTU with strong lashing points:

$MSL_{anchor\ point}$	Maximum securing load of container anchor point = 2000 daN
$MSL_{top\ lashing\ point}$	Maximum securing load of container top lashing point = 2000 daN

In order not to overstress the lower anchor points, the force in the lower part of the vertical lashings, F_1 , should be taken as the minimum of:

Max force due to rating of lashing: $F_1 = MSL_{vertical\ lashing} = 2000\ daN$
Max force due to rating of container roof lashing point: $F_1 = MSL_{anchor\ point}$

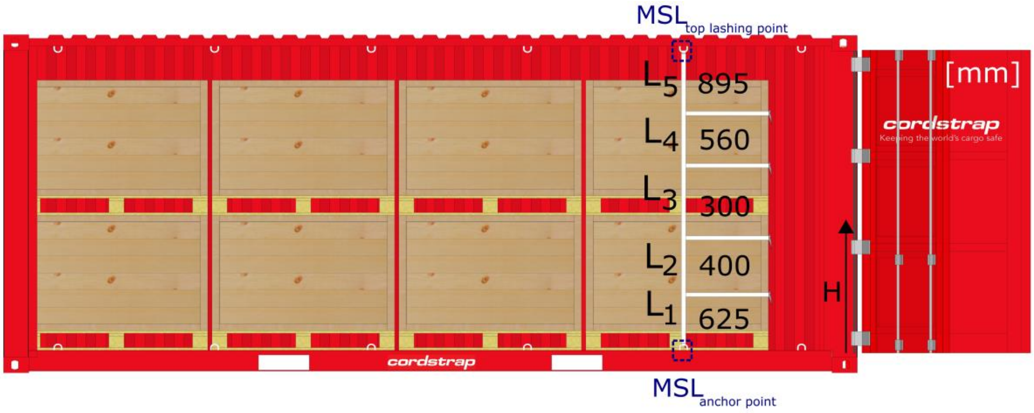
In order not to overstress the top lashing points, the force in the upper part of the vertical lashings, F_5 , should be taken as the minimum of:

Max force due to rating of lashing: $F_5 = MSL_{vertical\ lashing} = 2000\ daN$
Max force due to rating of container roof lashing point: $F_5 = MSL_{top\ lashing\ point}$

In order not to overstress the container securing points, the force in the horizontal lashings, L , should be taken as the minimum of:

Max force due to rating of lashing: $FL = MSL_{horizontal\ \ lashing} = 1125\ daN$

Max force due to rating of container securing points: $From\ formulas$



The previous set up formulas and the following in data is used to calculate the forces in the single Cordstrap QuickLash® SD & SD-R solution:

H	2.4 meter	L_3	0.3 meter
L_1	0.625 meter	L_4	0.56 meter
L_2	0.4 meter	L_5	0.895 meter

$MSL_{anchor\ point}$	1000 daN
$MSL_{top\ lashing\ point}$	500 daN

$MSL_{vertical\ lashing}$ 2000 daN in a system loop with snaphooks

$$F_5 = 500\ daN$$

When inserting F_5 = 500 daN in the formulas for case 1, F_1 becomes:

$$F_1 = 569\ daN$$

And the angles are after iteration:

$$\alpha_1 = 45.4\ degrees$$
$$\alpha_2 = 61.0\ degrees$$
$$\alpha_3 = 81.0\ degrees$$
$$\alpha_4 = 73.8\ degrees$$
$$\alpha_5 = 54.1\ degrees$$

$$FL_{1,2,3,4} = mean\ [FL1; FL2; FL3; FL4] = 173 \text{ daN}$$

It is assumed that the forces in the horizontal lashings are equal in all lashings.

Secured cargo weight

The secured cargo weight in ton, m, is calculated as:

$$m = \frac{2 \cdot 4 \cdot FL}{(c_h - c_v \cdot \mu \cdot f_\mu) * g * 100}$$

where:

c_h	*Horizontal acceleration coefficient*
c_v	*Vertical acceleration coefficient*
μ	*Friction factor*
f_μ	*Conversion factor for dynamic friction*
g	*Gravity acceleration 9.81 [m/s^2]*

Please note: These calculations exclude the positive effect of friction against the walls, which may only be accounted for based on practical tests, as different products in the bags behave differently.

Example calculation

For transport in sea area C with c_h = 0.4 backward, c_v = 0.2 downwards, the friction factor μ = 0.3 and a 20ft CTU with normal lashing points the following secured cargo weight in ton is obtained:

$$m = \frac{2 \cdot 4 \cdot 173}{(0.4 - 0.2 \cdot 0.3 \cdot 0.75) * 9.81 * 100} = 4.0\ ton$$

The same set of formulas and the following in data is used to calculate the forces in the single Cordstrap QuickLash® SD & SD-R solution in a container with strong securing points:

H	2.4 meter	L_3	0.42 meter
L_1	0.76 meter	L_4	0.42 meter
L_2	0.42 meter	L_5	0.76 meter

$MSL_{anchor\ point}$	2000 daN
$MSL_{top\ lashing\ point}$	2000 daN

$MSL_{vertical\ lashing}$ 2000 daN in a system loop with snaphooks

$$F_5 = 2000\ daN$$

When inserting F_5 = 2000 daN in the formulas for case 1, F_1 becomes:

$$F_1 = 1962\ daN$$

And the angles are after iteration:

$$\alpha_1 = 46.1\ degrees$$
$$\alpha_2 = 64.0\ degrees$$
$$\alpha_3 = 87.0\ degrees$$
$$\alpha_4 = 63.5\ degrees$$
$$\alpha_5 = 45.0\ degrees$$

$$FL_{1,2,3,4} = mean\ [FL1; FL2; FL3; FL4] = 693\ \text{daN}$$

It is assumed that the forces in the horizontal lashings are equal in all lashings.

Secured cargo weight

The secured cargo weight in ton, m, is calculated as:

$$m = \frac{2 \cdot 4 \cdot FL}{(c_h - c_v \cdot \mu \cdot f_\mu) * g * 100}$$

where:

c_h	*Horizontal acceleration coefficient*
c_v	*Vertical acceleration coefficient*
μ	*Friction factor*
f_μ	*Conversion factor for dynamic friction*
g	*Gravity acceleration 9.81 [m/s²]*

Please note: These calculations excludes the positive effect of friction against the walls, which may only be accounted for based on practical tests, as different products in the bags behave differently.

Example calculation

For transport in sea area C with c_h = 0.4 backward, c_v = 0.2 downwards, the friction factor μ = 0.3 and a 20ft CTU with normal lashing points the following secured cargo weight in ton is obtained:

$$m = \frac{2 \cdot 4 \cdot 693}{(0.4 - 0.2 \cdot 0.3 \cdot 0.75) * 9.81 * 100} = 15.9\ ton$$

Lashing tables - Cordstrap QuickLash® SD & SD-R solution

Each table gives the secured cargo weight in ton per lashing solution depending on the friction factor. The lashing tables are divided into two sections:

1. CTUs with normal lashing points - 1000 daN in anchor points and 500 daN in roof lashing points
2. CTUs with strong lashing points - 2000 daN in anchor points and roof lashing points

The tables are divided as follows for the different modes of transport:

1. The secured cargo weight in ton for a single Cordstrap QuickLash® SD & SD-R solution in a 20ft CTU consisting of 6 pieces of lashings, 3 buckles and 2 HangStraps or other sufficient means to keep the lashing in the right position.

2. The secured cargo weight in ton for a double Cordstrap QuickLash® SD & SD-R solution in a 20ft CTU consisting of two solutions each comprising consisting of 6 pieces of lashings, 3 buckles and 2 HangStraps or other sufficient means to keep the lashing in the right position.

3. The secured cargo weight in ton for a double Cordstrap QuickLash® SD & SD-R solution in a 40ft CTU consisting of two solutions each comprising consisting of 6 pieces of lashings, 3 buckles and 2 HangStraps or other sufficient means to keep the lashing in the right position.

Please note that the values of secured cargo weight might differ slightly for specific solutions with different dimensions.

The tables have been based on the accelerations in the IMO/ILO/UNECE Code of Practice for Packing of Cargo Transport Units (CTU Code).

1. Lashing tables – CTUs with normal lashing points

CTUs with a 1000 daN maximum securing load in the anchor points and 500 daN in roof lashing points.

Road transport (doors to the rear) and rail transport (doors in any direction)

Acceleration coefficients: c_h = 0.5 backward and c_v = 1.0 downwards

Single Cordstrap QuickLash® SD & SD-R solution (20ft)

Friction factor	Secured cargo weight (in ton) per single solution (20ft)
0.00	2.8
0.10	3.3
0.20	4.0
0.30	5.1
0.40	7.1
0.45	8.7
0.50	no slide
0.60	no slide
0.70	no slide

Double Cordstrap QuickLash® SD & SD-R solution (20ft)

Friction factor	Secured cargo weight (in ton) per double solution (20ft)
0.00	5.6
0.10	6.6
0.20	8.1
0.30	10.3
0.40	14.1
0.45	17.4
0.50	no slide
0.60	no slide
0.70	no slide

Double Cordstrap QuickLash® SD & SD-R solution (40ft)

Friction factor	Secured cargo weight (in ton) per double solution (40ft)
0.00	5.6
0.10	6.6
0.20	8.1
0.30	10.3
0.40	14.1
0.45	17.4
0.50	no slide
0.60	no slide
0.70	no slide

Road transport (doors to the front)

Acceleration coefficients: c_h = 0.8 forward and c_v = 1.0 downwards

Single Cordstrap QuickLash® SD & SD-R solution (20ft)

Friction factor	Secured cargo weight (in ton) per single solution (20ft)
0.00	1.8
0.10	1.9
0.20	2.2
0.30	2.5
0.40	2.8
0.45	3.1
0.50	3.3
0.60	4.0
0.70	5.1

Double Cordstrap QuickLash® SD & SD-R solution (20ft)

Friction factor	Secured cargo weight (in ton) per double solution (20ft)
0.00	3.5
0.10	3.9
0.20	4.3
0.30	4.9
0.40	5.6
0.45	6.1
0.50	6.6
0.60	8.1
0.70	10.3

Double Cordstrap QuickLash® SD & SD-R solution (40ft)

Friction factor	Secured cargo weight (in ton) per double solution (40ft)
0.00	3.5
0.10	3.9
0.20	4.3
0.30	4.9
0.40	5.6
0.45	6.1
0.50	6.6
0.60	8.1
0.70	10.3

Sea transport (Sea Area C – unrestricted)

Acceleration coefficients: c_h = 0.4 forward/backward and c_v = 0.2 downwards

Single Cordstrap QuickLash® SD & SD-R solution (20ft)

Friction factor	Secured cargo weight (in ton) per single solution (20ft)
0.00	3.5
0.10	3.7
0.20	3.8
0.30	4.0
0.40	4.1
0.45	4.2
0.50	4.3
0.60	4.6
0.70	4.8

Double Cordstrap QuickLash® SD & SD-R solution (20ft)

Friction factor	Secured cargo weight (in ton) per double solution (20ft)
0.00	7.1
0.10	7.3
0.20	7.6
0.30	7.9
0.40	8.3
0.45	8.5
0.50	8.7
0.60	9.1
0.70	9.6

Double Cordstrap QuickLash® SD & SD-R solution (40ft)

Friction factor	Secured cargo weight (in ton) per double solution (40ft)
0.00	7.1
0.10	7.3
0.20	7.6
0.30	7.9
0.40	8.3
0.45	8.5
0.50	8.7
0.60	9.1
0.70	9.6

2. Lashing tables – CTUs with strong lashing points

CTUs with a 2000 daN maximum securing load in the anchor points and roof lashing points.

Road transport (doors to the rear) and rail transport (doors in any direction)

Acceleration coefficients: c_h = 0.5 backward and c_v = 1.0 downwards

Single Cordstrap QuickLash® SD & SD-R solution (20ft)

Friction factor	Secured cargo weight (in ton) per single solution (20ft)
0.00	11.3
0.10	13.3
0.20	16.1
0.30	20.6
0.40	28.3
0.45	34.8
0.50	no slide
0.60	no slide
0.70	no slide

Double Cordstrap QuickLash® SD & SD-R solution (20ft)

Friction factor	Secured cargo weight (in ton) per double solution (20ft)
0.00	22.6
0.10	26.6
0.20	32.3
0.30	41.1
0.40	56.5
0.45	69.6
0.50	no slide
0.60	no slide
0.70	no slide

Double Cordstrap QuickLash® SD & SD-R solution (40ft)

Friction factor	Secured cargo weight (in ton) per double solution (40ft)
0.00	22.6
0.10	26.6
0.20	32.3
0.30	41.1
0.40	56.5
0.45	69.6
0.50	no slide
0.60	no slide
0.70	no slide

Road transport (doors to the front)

Acceleration coefficients: c_h = 0.8 forward and c_v = 1.0 downwards

Single Cordstrap QuickLash® SD & SD-R solution (20ft)

Friction factor	Secured cargo weight (in ton) per single solution (20ft)
0.00	7.1
0.10	7.8
0.20	8.7
0.30	9.8
0.40	11.3
0.45	12.2
0.50	13.3
0.60	16.1
0.70	20.6

Double Cordstrap QuickLash® SD & SD-R solution (20ft)

Friction factor	Secured cargo weight (in ton) per double solution (20ft)
0.00	14.1
0.10	15.6
0.20	17.4
0.30	19.7
0.40	22.6
0.45	24.4
0.50	26.6
0.60	32.3
0.70	41.1

Double Cordstrap QuickLash® SD & SD-R solution (40ft)

Friction factor	Secured cargo weight (in ton) per double solution (40ft)
0.00	14.1
0.10	15.6
0.20	17.4
0.30	19.7
0.40	22.6
0.45	24.4
0.50	26.6
0.60	32.3
0.70	41.1

Sea transport (Sea Area C – unrestricted)

Acceleration coefficients: c_h = 0.4 forward/backward and c_v = 0.2 downwards

Single Cordstrap QuickLash® SD & SD-R solution (20ft)

Friction factor	Secured cargo weight (in ton) per single solution (20ft)
0.00	14.1
0.10	14.7
0.20	15.3
0.30	15.9
0.40	16.6
0.45	17.0
0.50	17.4
0.60	18.2
0.70	19.2

Double Cordstrap QuickLash® SD & SD-R solution (20ft)

Friction factor	Secured cargo weight (in ton) per double solution (20ft)
0.00	28.3
0.10	29.4
0.20	30.5
0.30	31.8
0.40	33.2
0.45	34.0
0.50	34.8
0.60	36.5
0.70	38.3

Double Cordstrap QuickLash® SD & SD-R solution (40ft)

Friction factor	Secured cargo weight (in ton) per double solution (40ft)
0.00	28.3
0.10	29.4
0.20	30.5
0.30	31.8
0.40	33.2
0.45	34.0
0.50	34.8
0.60	36.5
0.70	38.3