Cargo Handling Instructions

- Stowage and securing of cars

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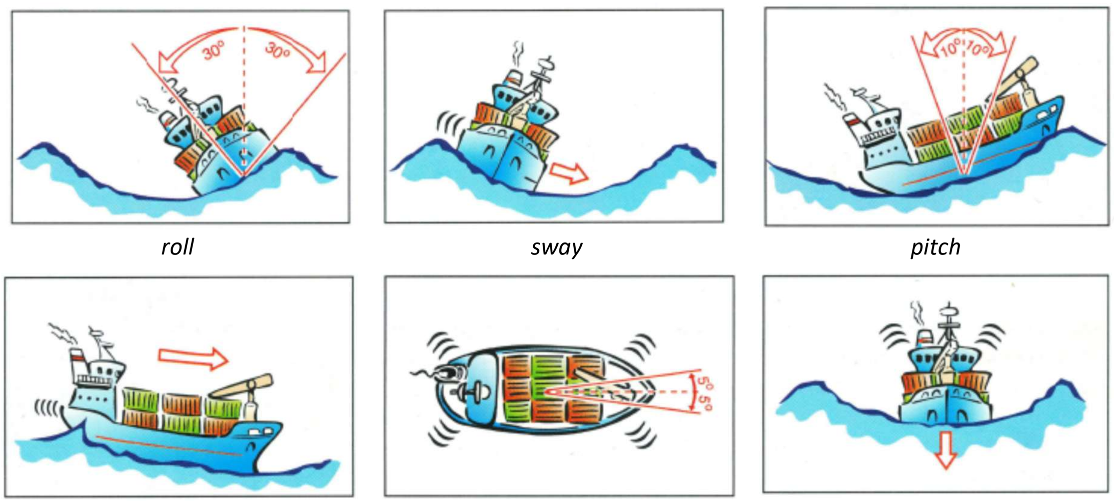
1 Evaluation of forces acting on cargo units

Cargo shifting on board a ship is normally due to ship motions at sea in bad weather, and thus it is necessary to secure the cargo in one way or the other. In what manner the cargo is to be secured depends on the route and the type of cargo to be shipped.

A ship at sea has six modes of motion: three rotational and three linear motions. The designations of these are pitch, roll, yaw, sway, surge and heave, see figures below.



roll *sway* *pitch*

surge *yaw* *heave*

Ship's modes of motion

1.1 Maximum allowed accelerations

The dimensioning accelerations in different positions on board have been calculated according to Annex 13 of the Code of Safe Practice for Cargo Stowage and Securing, which are presented in the diagrams below. The acceleration data is valid for loading conditions with GM values up to 3.00 m.

The figures given for transverse accelerations include components of gravity, roll, pitch and heave parallel to the deck. The vertical acceleration is the dynamic acceleration. The total vertical acceleration including gravity is thus 9.81 ± a_v, where a_v is taken from the figure below.

The below accelerations are the maximum on the different decks onboard WWO operated vessels. Actual accelerations on board individual vessels can be found in chapter 3 in the vessel's Cargo Securing Manual (CSM).

To avoid excessive longitudinal accelerations the speed will have to be reduced in extreme heavy head seas.

Accelerations for unrestricted voyages:

***Transverse accelerations a_t** [m/s^2]*

	Hold 4		Hold 3			Hold 2			Hold 1			***Longitudinal accelerations a_l** [m/s^2]*
On deck, high	6.65	6.38	6.20	6.11	6.02	6.02	6.11	6.20	6.38	6.65	7.00	3.00
On deck, low	5.87	5.70	5.52	5.35	5.35	5.35	5.35	5.52	5.70	5.87	6.13	2.30
Tween-deck	5.26	5.01	4.75	4.67	4.58	4.58	4.67	4.75	5.01	5.26	5.60	1.60
Lower hold			4.40	4.24	4.15	4.15	4.24	4.40	4.57	4.90		1.20
	Hold 4		*Hold 3*			*Hold 2*			*Hold 1*			*Holds*
***Vertical accelerations a_v** [m/s^2]*	7.30	6.04	4.93	3.97	3.42	3.42	3.97	4.93	6.04	7.30	8.70	

Accelerations in m/s^2 on different decks and stowage positions.

Deck levels and ramp positions on PCTC vessels

As per the CSS Code, deck levels are classified as *Lower Hold*, *Tween-deck*, *On Deck, Low*, and *On Deck, High*. On large PCTC vessels, this typically corresponds to:

- On Deck, High: Decks 10–12
- On Deck, Low: Decks 7–9
- Tween-deck: Decks 4–6 (incl. Main Deck)
- Lower Hold: Decks 1–3

On larger vessels, additional decks may exist, and the numbering may vary. For deck layouts on specific vessels, refer to chapter 3 of the vessel's Cargo Securing Manual (CSM).

Ramp positions vary between vessels. Most vessels are equipped with internal ramps inclined at less than 10 degrees, which is the basis for the calculations for cars. For high and heavy units, calculations are based on a maximum ramp inclination of 8 degrees.

1.2 Approximate coefficients of friction

One important parameter influencing the cargo securing system is the friction between the cargo unit and the ship's deck. According to Annex 13, section 7.2 and Appendix 4 of the document MSC.1/Circ.1623 Amendments to the Code of Safe Practice for Cargo Stowage and Securing (CSS Code), the following coefficient of friction (μ) may be used for cars and other self-propelled vehicles on air rubber tyres:

- Steel–air rubber tyre, dry and clean: 0.45

The coefficient of friction is to be regarded as dynamic friction coefficients which shall be used for direct lashings used on board.

If rolling cargoes having non-braked, non-driving wheels there is no work of friction at these wheels in the vehicle's driving direction unless chocks are used. The reduction is proportional to the part of weight on unbraked wheels. For cars and light rolling units with weight up to 3.5 ton the weight distribution is estimated to 50% on the braked axle. The parking brake is mandatory to be engaged to make the calculations valid.

1.3 Safety factors

Safety factors are needed for uncertainties in both the calculations and in the strength of securing devices.

1.3.1 Safety factors for calculations

There are uncertainties in the calculations of required forces in securing arrangements due to the possibility of uneven distribution of forces among the securing devices. To cover these uncertainties a safety factor should be used. The factor is set to either 1.20 or 1.35.

The required maximum securing load MSL of the securings are to be calculated according to the following equations, based on the largest calculated force in the lashings, FL_{max}:

- For lashing arrangements with more than four lashings working together:

  $MSL \geq FL_{max} \cdot 1.35$

- For lashing arrangements with maximum two lashings working in each direction:

  $MSL \geq FL_{max} \cdot 1.20$

1.3.2 Safety factors for securing devices

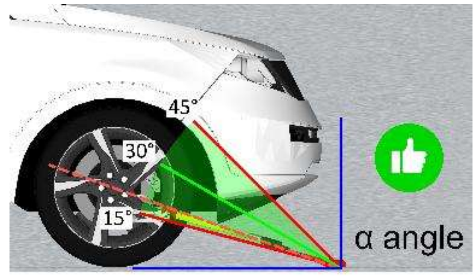
The maximum securing load (MSL) of securing equipment in relation to its minimum break load (MBL) to be according to the figure below.

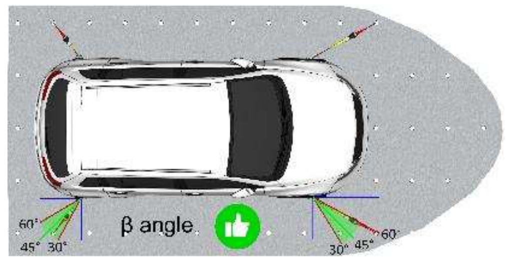
Material	MSL
Web Lashing	50 % of MBL

Maximum securing load, MSL, in relation to minimum break load, MBL

1.4 Lashing angles

In the examples in this document the lashings direction is defined by the angles α and β which are explained in the figure to the right.





α = Vertical lashing angle
β = Longitudinal lashing angle between the lashing and the transverse axle of the cargo transport unit seen from above

The lashing angles are to be used for dimensioning lashing arrangements for the following four cases:

- Transverse sliding
- Longitudinal sliding
- Transverse tipping
- Longitudinal tipping (not an issue for cars)

The following angles should be used when securing cargo units:

- For cars with a weight up to 3.5 ton the α-angle should be between 15 - 45° and the β-angle between 30 - 60°.

When calculating lashing forces in cargo securing arrangements the maximum and minimum values for the α and the β angles should be applied as follows:

- α_{max} is to be used in sliding equations and α_{min} is to be used in tipping equations.

- β_{max} is to be used in combination with transverse accelerations and β_{min} is to be used in combination with longitudinal accelerations.

The lashing interval may be outside of the prescribed lashing interval if the Cargo Securing Manual for the ship is stating that this is allowed. Examples showing how the secured weight can be calculated are found in the Appendix – Calculation Examples.

1.5 Statement on mixed lashings

Mixed lashings, i.e., a combination of lashings attached to a vehicle's lashing eyes and lashings attached to the rims, should generally be avoided, as they may create an uneven distribution of forces between the lashings:

Different lashing lengths

Car lashings stretch when subjected to dynamic forces during transport. If lashings of unequal length are used, they will stretch by different amounts. This can cause vehicles to move inconsistently in both longitudinal and athwartships directions, increasing the risk of damage to the vehicle itself or to surrounding cargo.

Symmetry of the lashing arrangement

When securing vehicles, the lashing arrangement should always be as symmetrical as possible. Symmetry ensures a more balanced distribution of forces between lashings working in different directions. In all cases, the prescribed lashing angle interval must be respected.

Permitted use of mixed lashings

In some situations, mixed lashings may be acceptable, provided the work is carried out under sufficient supervision to ensure that the following conditions are met:

- The lashings attached to the vehicle's lashing eyes and those attached to the rims should, as far as practicable, be of equal length.
- The prescribed lashing angle interval must always be followed.

1.6 Application of chocks

When used for cars, the chocks shall always be positioned on the front axle in the driving direction of the vehicle.

Car with two chocks placed around one front wheel.

Car with four chocks placed around the front wheels.

1.6.1 Securing and chocking of cars

When chocking cars, the chocks shall always be placed at the unbraked axle. As outlined in the drivetrain overview in section 1.6.2 below, the most critical case is a rear-wheel drive (RWD) vehicle, where both the parking brake and the transmission lock act on the rear axle. This leaves the front axle unbraked, which is where the chocks must be positioned.

For dimensioning cargo securing arrangements, chocks are required for cars stowed athwartships. When correctly placed on the unbraked axle, the chocks ensure that friction is produced at both axles and they increase the efficiency of the lashings in the securing calculations, resulting in a higher securing value.

1.6.2 Explanation of different drive trains of cars

FWD (front-wheel drive):

- Driving wheels: Front
- Parking brake: Locks rear axle
- Gear / P: Holds front axle (since transmission locks the driven wheels)
- → Both axles secured when using brake + gear/P.

RWD (rear-wheel drive):

- Driving wheels: Rear
- Parking brake: Locks rear axle
- Gear / P: Holds rear axle (transmission locks driven wheels)
- → Rear axle double-secured, front axle free.

4WD / AWD (four-wheel drive):

- Driving wheels: Both axles (distribution varies by system)
- Parking brake: Locks rear axle
- Gear / P: Holds both axles (since transmission connects to front and rear)
- → Entire driveline secured.

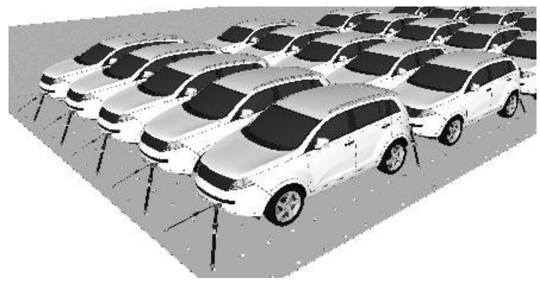
2 Cargo securing arrangements for different cargo types

This chapter describes the correct application of portable cargo securing gear to the following types of units:

- Cars and light rolling units (0 – 3.5 ton) section: 2.1

2.1 Cars and light rolling units, 0 – 3.5 ton

All decks intended for transport of cars and lighter vehicles have fixed securing arrangements in the decks. The car should be put in a low gear and the parking brake activated. Normal stowing of cars is in fore and aft direction. However, to utilize all available space, it is sometimes necessary to stow some of the cars athwartships.



Car lashings, car chocks and car slings are the only equipment to be used for lashing of cars. If the car doesn't have designated lashing points, car slings may be used for attaching car lashings to the rims. Multiple car lashings should not be attached to a car sling.

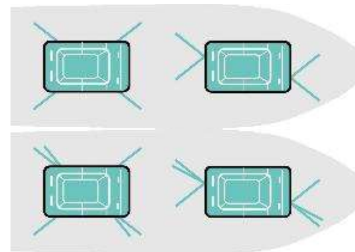
The tables below indicate the maximum weight for cars for longitudinally and athwartships stowed cars respectively as well as car stowed in ramps. The α-angle of the car lashings should be between 15 - 45 degrees and the β-angle between 30 - 60 degrees.

Note! *If the angles are outside the permissible intervals the number of lashings must be increased.*

Example calculations on securing arrangement for cars are given in the appendix of this document. It has been assumed that 50% of the weight rest on the braked axle. The dynamic coefficient of friction has been taken as 0.45 for air rubber tyres against the deck plating.

2.1.1 Longitudinally stowed cars

The table below indicates the maximum permissible weight for longitudinally stowed cars that have been secured with 4 lashings, 2 per end. If the limited weights in the table below are exceeded, extra car lashings must be applied in each end according to the instructions.



Typical deck levels:*				
Deck 10 and above	2.9 ton			2.6 ton
Deck 7-9				
Deck 4-6 (incl. main deck)				
Deck 1-3				
Holds	*Hold 4*	*Hold 3*	*Hold 2*	*Hold 1*

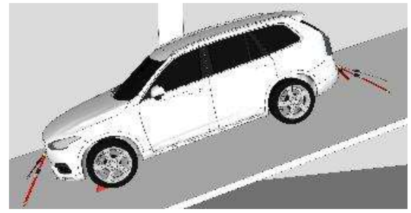
**) On large PCTC vessels, the deck levels typically correspond to the divisions described above. For the exact division of deck levels, please refer to the vessel's Cargo Securing Manual.*

(green)	Max weight 3.5 ton: 4 lashings, 2 per end
(orange)	Limited weight or extra securing: 1 extra car lashing should be applied in each end

In heavy head seas, the vessel's speed must be reduced to limit excessive longitudinal and vertical forces.

2.1.2 Cars stowed in ramps

The table below indicates the maximum permissible weight for cars loaded longitudinal in rampways that have been secured with 4 lashings, 2 per end, and at least 2 car chocks placed in downhill direction. If the limited weights in the table below are exceeded, extra car lashings must be applied according to the instructions.



Typical deck levels:*	*Hold 4*	*Hold 3*	*Hold 2*	*Hold 1*
Deck 10 and above	2.1 ton	2.1 ton	2.1 ton	2.1 ton
Deck 7-9	2.8 ton	2.8 ton	2.8 ton	2.8 ton
Deck 4-6 (incl. main deck)				
Deck 1-3				

Holds

**) On large PCTC vessels, the deck levels typically correspond to the divisions described above. For the exact division of deck levels, please refer to the vessel's Cargo Securing Manual.*

	Max weight 3.5 ton: 4 lashings, 2 per end, and at least 2 car chocks placed in downhill direction
	Limited weight or extra securing: 1 extra car lashing should be applied upwards
	Limited weight or extra securing: 2 extra car lashings should be applied upwards and 1 extra car lashing should be applied downwards

In heavy head seas, the vessel's speed must be reduced to limit excessive longitudinal and vertical forces.

2.1.3 Athwartships stowed cars

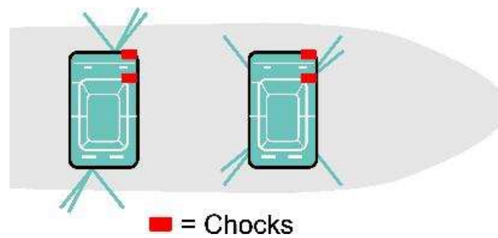
This section for athwartships stowed cars contains two sub-sections with lashing tables based on:

- Maximum secured weight when 6 lashings and at least 2 car chocks are used
- Number of lashings and chocks needed for securing of cars weighing up to 3.5 tons

2.1.3.1 Maximum secured weight when 6 lashings and at least 2 car chocks are used

The table below indicates the maximum permissible weight for athwartships stowed cars when 6 lashings, 3 per end, and at least 2 car chocks are used.

If the limited weights in the table below are exceeded, see section 2.1.3.2 for cars with higher weights.



Typical deck levels:*	*Hold 4*	*Hold 3*	*Hold 2*	*Hold 1*
Deck 10 and above	2.0 ton	2.0 ton	2.0 ton	2.0 ton
Deck 7-9	2.5 ton	2.5 ton	2.5 ton	2.5 ton
Deck 4-6 (incl. main deck)				2.5 ton
Deck 1-3				

Holds

**) On large PCTC vessels, the deck levels typically correspond to the divisions described above. For the exact division of deck levels, please refer to the vessel's Cargo Securing Manual.*

(green)	Max weight 3.5 ton: 6 lashings, 3 per end, and at least 2 car chocks
(yellow)	Limited weights: 6 lashings, 3 per end, and at least 2 car chocks

For athwartships stowed cars weighing maximum 1.5 ton, the following minimum requirements apply:

Deck 9 and below:

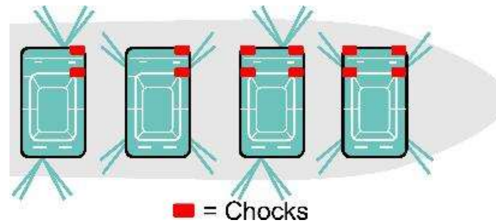
2 + 2 lashings and 2 wedges

Deck 10 and above:

3 + 3 lashings and 2 wedges

2.1.3.2 *Number of lashings and chocks needed for securing of cars weighing up to 3.5 tons*

The table below indicates the maximum permissible weight for athwartships stowed cars.



The green colour – cars secured with 6 lashings, 3 per end, and at least 2 car chocks placed around one front wheel.

The yellow colour – cars secured with 8 lashings, 4 per end, and at least 2 car chocks placed around one front wheel.

The orange colour – cars secured with 8 lashings, 4 per end, and at least 4 car chocks placed around the front wheels.

The red colour – limited weight is possible for cars secured with 8 lashings, 4 per end, and at least 4 car chocks placed around the front wheels.

Typical deck levels:*				
Deck 10 and above				3.4 ton
Deck 7-9				
Deck 4-6 (incl. main deck)				
Deck 1-3				
Holds	*Hold 4*	*Hold 3*	*Hold 2*	*Hold 1*

**) On large PCTC vessels, the deck levels typically correspond to the divisions described above. For the exact division of deck levels, please refer to the vessel's Cargo Securing Manual.*

	Max weight 3.5 ton: 6 lashings, 3 per end, and at least 2 car chocks
	Max weight 3.5 ton: 8 lashings, 4 per end, and at least 2 car chocks
	Max weight 3.5 ton: 8 lashings, 4 per end, and at least 4 car chocks
	Limited weight: 8 lashings, 4 per end, and at least 4 car chocks

3 Appendix – Calculation Examples

This appendix contains guidance for performing calculations on the dimensioning of cargo securing arrangements for specific cargo units. The first part of this appendix contains formulas for performing the calculations. In the second part examples are given on how to use the formulas.

For explanation of the angles α and β, see section 1.4 Lashing angles.

3.1 Formulas

Below formulas for calculating the cargo weight in ton prevented from sliding and tipping is given for lashing arrangements.

Transverse sliding:

$$m = \frac{\sum_{i=1}^{n}\left[\frac{MSL_i}{SF}\cdot(\mu\cdot c_{FL}\cdot sin\alpha_i + cos\alpha_i\cdot cos\beta_i)\right]}{\frac{a_t}{PF} - \mu\cdot c_m\cdot g_0}$$

Longitudinal sliding:

$$m = \frac{\sum_{i=1}^{n}\left[\frac{MSL_i}{SF}\cdot(\mu\cdot c_{FL}\cdot sin\alpha_i + cos\alpha_i\cdot sin\beta_i)\right]}{\frac{a_l}{PF} - \mu\cdot c_m\cdot (g_0 - f_z\cdot a_v)}$$

Transverse tipping:

$$m = \frac{\sum_{i=1}^{n}\left[\frac{MSL_i}{SF}\cdot(p_i\cdot sin\alpha_i + s_i\cdot cos\alpha_i\cdot cos\beta_i)\right]}{\frac{a_t}{PF}\cdot H_{CG} - g_o\cdot B_{CG}}$$

Longitudinal tipping:

$$m = \frac{\sum_{i=1}^{n}\left[\frac{MSL_i}{SF}\cdot(p_i\cdot sin\alpha_i + s_i\cdot cos\alpha_i\cdot sin\beta_i)\right]}{\frac{a_l}{PF}\cdot H_{CG} - (g_0 - f_z\cdot a_v)\cdot L_{CG}}$$

General parameters		**Unit**
m =	Mass of the load	ton (=1000 kg)
n =	Number of lashing working together in each direction	-
i =	Index for lashing (i = 1, 2, 3, 4 …. n)	-
c_m =	Part of mass resting on braked/wedged axle/support (in rolling direction) = 1 for vehicles where all axles are braked, as well as static cargo = 0.5 for cars & light rolling units braked on one axle = 0.2 for axles with two chocks = 0.4 for axles with four chocks = 0.3 for roll trailers = 0 if none of the axles are braked	-
c_{FL} =	Factor to determine whether the lashing increases friction or not (in rolling direction) = 1 if the lashing/lashings increase the friction = 0 if the lashing/lashings do not increase the friction	-
PF =	Performance factor of 1.15 for voyages less than 72 hours. For voyages more than 72 hours, the factor is set to 1. a_l and a_t are divided by this factor	-
f_z =	Reduction factor for longitudinal sliding and tipping. fz is taken as the average friction for the whole contact surface. (see table below) Linear interpolation is used to obtain intermediate values not found in the table	-

μ	0.0	0.1	0.2	0.3	0.4	0.6
f_z	0.20	0.50	0.70	0.80	0.85	0.90

Accelerations		**Unit**
g_0 =	Gravitational acceleration (= 9.81 m/s^2)	m/s^2

a_l =	Longitudinal acceleration	m/s²
a_t =	Transverse acceleration	m/s²
a_v =	Vertical acceleration	m/s²

Friction

μ =	Coefficient of friction	-

Properties of the lashing device

MSL =	Maximum Securing Load/Lashing capacity of a lashing device	kN (= 100 daN)

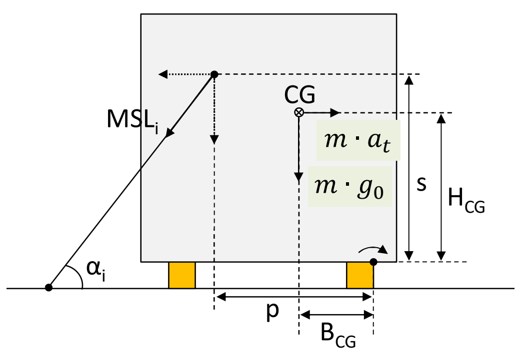
Angles

α =	Vertical lashing angle	degrees
β =	Longitudinal lashing angle between the lashing and the transverse axle of the cargo transport unit seen from above	degrees
SF =	Safety factor; 1.20 if 2 lashings are working in each direction, 1.35 if more than 4 lashings are used	-

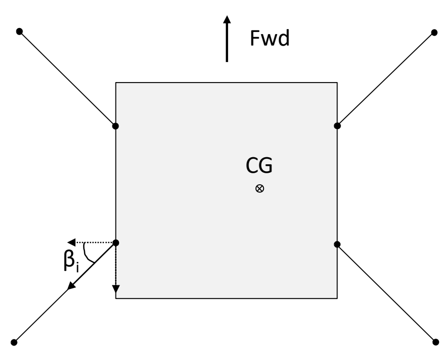
Distances (see figure below)

B_{CG} =	Transverse distance from the centre of gravity of the load to the tipping point (lever arm of standing moment)	m
L_{CG} =	Longitudinal distance from the centre of gravity of the load to the tipping point (lever arm of standing moment)	m
H_{CG} =	Vertical distance from the centre of gravity of the load to the tipping point (lever arm of tilting moment)	m
s =	Vertical distance from the tipping point to the point where the lashing device acts on the load	m
p =	Horizontal distance from the tipping point to the point where the lashing device acts on the load	m

Distances in tipping equations



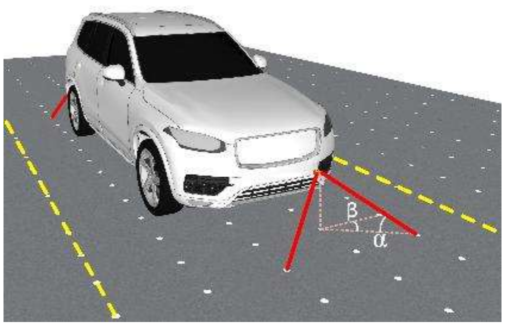
View from the end



View from above

3.2 Example calculation – Cars/HSV, longitudinal stowed – weight 3.5 ton

A car weighing 3.5 ton, braked on one axle, is stowed longitudinally on deck, high at hold 2. The unit is secured by four car lashings with MSL 1 ton according to the sketch below. The maximum mass of the car prevented from sliding in **transverse and longitudinal direction** is calculated by the advanced formulas.



Number of lashings are 2 per end => SF = 1.20

Data:
$\mu = 0.45$
$a_t = 6.20\ m/s^2$
$a_l = 3.00\ m/s^2$
$a_v = 4.93\ m/s^2$
$g_0 = 9.81\ m/s^2$
$f_z = 0.725$

Lashings:
$\alpha = 15 - 45°$
$\beta = 30 - 60°$
MSL = 1 ton ≈ 10 kN

Transverse sliding:
50% of weight on braked axle =>
$c_m = 1$
$c_{FL} = 1$

Longitudinal sliding:
50% of weight on braked axle =>
$c_m = 0.5$
$c_{FL} = 0$

Transverse sliding
For transverse sliding the following equation for the secured mass m can be set up:

$$m = \frac{\sum_{i=1}^{n}\left[\frac{MSL_i}{SF} \cdot (\mu \cdot c_{FL} \cdot sin\alpha_i + cos\alpha_i \cdot cos\beta_i)\right]}{\frac{a_t}{PF} - \mu \cdot c_m \cdot g_0}$$

With the values according to the figure above the equation will be:

$$m = \frac{2 \cdot \frac{10}{1.20} \cdot (0.45 \cdot 1 \cdot sin15° + cos15° \cdot cos60°)}{\frac{6.20}{1} - 0.45 \cdot 1 \cdot 9.81} = 5.59\ ton$$

Longitudinal sliding
For longitudinal sliding the following equation is set up:

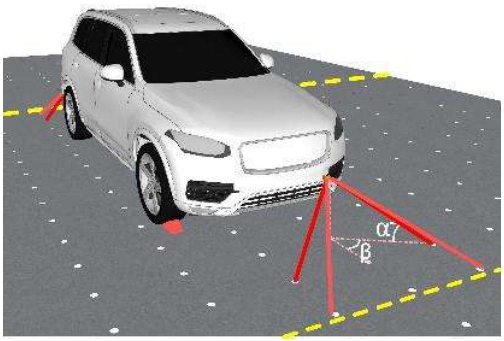
$$m = \frac{\sum_{i=1}^{n}\left[\frac{MSL_i}{SF} \cdot (\mu \cdot c_{FL} \cdot sin\alpha_i + cos\alpha_i \cdot sin\beta_i)\right]}{\frac{a_l}{PF} - \mu \cdot c_m \cdot (g_0 - f_z \cdot a_v)}$$

Note that the lashings at the non-braked axle do not increase the work of friction and thus the factor $\mu \cdot c_{FL} \cdot sin\alpha_i = \mu \cdot 0 \cdot sin\alpha_i$ will not be included in the equation. With the values according to the figure above the equation will be:

$$m = \frac{2 \cdot \frac{10}{1.20} \cdot cos45° \cdot sin30°}{\frac{3.00}{1} - 0.45 \cdot 0.5 \cdot (9.81 - 0.725 \cdot 4.93)} = 3.69\ ton$$

3.3 *Example calculation – Cars/HSV, athwartships stowed – weight 3.5 ton*

A car weighing 3.5 ton, braked on one axle, is stowed athwartships on deck, high at hold 2. The unit is secured by eight car lashings with MSL 1 ton according to the sketch below as well as four car chocks. The maximum mass of the car prevented from sliding in **transverse and longitudinal direction** is calculated by the advanced formulas.



Number of lashings are 4 per end => SF = 1.35

Data:
$\mu = 0.45$
$a_t = 6.20\ m/s^2$
$a_l = 3.00\ m/s^2$
$a_v = 4.93\ m/s^2$
$g_0 = 9.81\ m/s^2$
$f_z = 1$

Lashings:
$\alpha = 15 - 45°$
$\beta = 30 - 60°$
MSL = 1 ton ≈ 10 kN

Longitudinal sliding:
50% of weight on braked axle =>
$c_m = 1$
$c_{FL} = 1$

Transverse sliding:
50% of weight on braked axle and four car chocks=>
$c_m = 0.9$
$c_{FL} = 0$

Transverse sliding
For transverse sliding the following equation for the secured mass m can be set up:

$$m = \frac{\sum_{i=1}^{n}\left[\frac{MSL_i}{SF}\cdot(\mu\cdot c_{FL}\cdot sin\alpha_i + cos\alpha_i\cdot cos\beta_i)\right]}{\frac{a_t}{PF} - \mu\cdot c_m\cdot g_0}$$

Note that the lashings at the non-braked axle do not increase the work of friction and thus the factor $\mu\cdot c_{FL}\cdot sin\alpha_i = \mu\cdot 0\cdot sin\alpha_i$ will not be included in the equation. With the values according to the figure above the equation will be:

$$m = \frac{4\cdot\frac{10}{1.35}\cdot cos45°\cdot cos60°}{\frac{6.20}{1} - 0.45\cdot 0.9\cdot 9.81} = 4.70\ ton$$

Longitudinal sliding
For longitudinal sliding the following equation is set up:

$$m = \frac{\sum_{i=1}^{n}\left[\frac{MSL_i}{SF}\cdot(\mu\cdot c_{FL}\cdot sin\alpha_i + cos\alpha_i\cdot sin\beta_i)\right]}{\frac{a_l}{PF} - \mu\cdot c_m\cdot (g_0 - f_z\cdot a_v)}$$

With the values according to the figure above the equation will be:

$$m = \frac{4\cdot\frac{10}{1.35}\cdot (0.45\cdot 1\cdot sin15° + cos15°\cdot sin30°)}{\frac{3.00}{1} - 0.45\cdot 1\cdot (9.81 - 1\cdot 4.93)} = 22.1\ ton$$