



## **RULES**

### **PUBLICATION 32/P**

#### **REQUIREMENTS CONCERNING STOWAGE AND LASHING OF CARGOES ON SEA-GOING SHIPS**

January  
2023

Publications P (Additional Rule Requirements) issued by Polski Rejestr Statków  
complete or extend the Rules and are mandatory where applicable.

GDAŃSK

*Publication 32/P – Requirements Concerning Stowage and Lashing of Cargoes of Sea-going Ships – January 2023* is an extension of the requirements contained in *Part I – Classification Regulations of the Rules for the Classification and Construction of Sea-Going Ships*.

This Publication was approved by PRS Board on 12 December 2022 and enters into force on 1 January 2023.

This Publication also applies to other PRS regulations if it is mentioned there.

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## 1 GENERAL PROVISIONS

### 1.1 Application

**1.1.1** This *Publication* applies to the classified by PRS general purpose sea-going ships operated in accordance with good seamanship rules which are intended for carriage of all cargoes other than dry and liquid bulk cargoes and for carriage of timber deck cargoes.

**1.1.2** Referred to in this *Publication*:

- Part I – Classification Regulations
- Part II – Hull
- Part III – Hull Equipment
- Part IV – Stability and Subdivision
- Part IX – Materials and Welding

are parts of the *Rules for Classification and Construction of Sea-going Ships* issued by PRS.

**1.1.3** This *Publication* contains complementary requirements necessary to be met in order to obtain the appropriate additional marks in the class notation.

### 1.2 Technical Documentation

**1.2.1** The complete set of technical documentation relevant to the object of this *Publication*, which is subject to approval by PRS, includes:

- .1 Stowage and lashing plan for containers giving their weight and the list of securing devices.
- .2 Lay-out plan of container sockets and lashing points.
- .3 Stowage and lashing plan for road vehicles and roll-trailers giving their weight and the list of the securing devices for road vehicles and roll-trailers.
- .4 Lay-out plan of sockets and lashing points for road vehicles and roll-trailers.
- .5 Stowage and lashing plan for timber deck cargo giving its weight and the list of the securing devices including the lashing calculations.
- .6 Cargo Securing Manual prepared to meet the requirements specified in the *Revised Guidelines for the Preparation of the Cargo Securing Manual* (IMO MSC./Circ.1353/Rev.2), *Code of Safe Practice for Cargo Stowage and Securing* with the Annexes thereto (Assembly Resolution A.714(17)), and *Code of Safe Practice for Ships Carrying Timber Deck Cargoes* (Resolution IMO A. 1048(27)) and the appended amendments.

**1.2.2** Documentation within the applicable scope, taking into account the ship type, her equipment and outfitting, shall be submitted to PRS Head Office for approval.

**1.2.3** If reasonably justified, PRS may extend the scope of the required documentation.

## 2 CARGO POSITIONING AND LASHING FITTINGS

### 2.1 General Requirements and Application

**2.1.1** This Chapter applies to the stowage and lashing equipment for containers, road vehicles and roll-trailers as well as timber deck cargoes on sea-going ships.

This cargo stowage and lashing equipment is divided into:

- .1 fixed securing devices – arrangements for stowage and lashing of cargo such as deck sockets, lashing points, upright seats, etc., permanently connected to the ships structure,

.2 portable securing devices – cargo stowage and lashing equipment intended for the stowage of cargo, such as lashings, tensioners, turnbuckles, stowage cones, stacking cones, bridge fittings, lashings, pulley blocks etc., not permanently connected to the ship's structure.

**2.1.2** The requirements of this Chapter apply to the securing devices in the ro-ro ships, ferries and on the ships intended and equipped for carriage of containers, road vehicles and roll-trailers. They also apply to the securing devices in the ships intended for carriage of timber deck cargo.

**2.1.3** Each ship intended to carry the cargoes specified in 2.1.1 shall be provided with the necessary number of securing devices. The necessary number of securing devices is understood as adequate permanent and/or portable equipment securing the cargo against movement during the transport to avoid any damage to the hull structure or ship stability loss.

**2.1.4** The cargo securing devices on the ships specified in 2.1.2 shall be chosen in accordance with the requirements of this *Publication*. In the case there are no specific requirements, the fittings shall be chosen in agreement with PRS.

**2.1.5** Permanent and portable securing devices are subject to the survey by PRS or approval by PRS after completion of a test programme agreed with PRS.

**2.1.6** The requirement specified in 2.1.5 applies to the securing devices provided in ships who have, in their symbol of class, additional marks such as **CONTAINER SHIP, ACC, RO-RO SHIP, FERRY, FERRY/PASSENGER SHIP** and **SD** or **MD** defined in 3.4 of *Part I – Classification Regulations*, and also to the fittings provided in ships who have, in their symbol of class, additional mark **TIMBER** if any part of the volume of timber deck cargo has been taken into account in the calculations of the ship cross curve.

**2.1.7** Only the securing devices specified in the list included in the documentation approved by PRS can be applied for cargo lashing. Devices designed for securing of the particular type of cargo may not be used for stowage and lashing of other types of cargo.

**2.1.8** Maximum Securing Load (*MSL*) is a term defining the allowable load capacity for a device used to secure the cargo on a ship. Maximum Securing Load shall be determined in accordance with the requirements specified in Table 2.1.8.

**Table 2.1.8**  
**Maximum Securing Load for specific securing devices**

Securing devices	<i>MSL</i>
Shakles, rings, deck-eyes, tensioners, twistlocks, bridge fittings, stacking cones, lashing rods, lashing chains, etc.	50% of breaking load
Fibre ropes	33% of breaking load
Web lashings	70% of breaking load
Wire ropes (brand new)	80% of breaking load
Wire ropes (re-used)	30% of breaking load
Steel bands (brand new)	70% of breaking load
Chains	50% of breaking load

## 2.2 Scope of Survey

**2.2.1** The technical survey of PRS concerning the stowage and lashing equipment covers: approval of documentation, survey of manufacturing and installation on board and testing of the arrangements and periodical surveys of the securing devices on the ship in service.

**2.2.2** The ship owner is responsible for maintenance, testing, continuous survey and keeping of ongoing records of the cargo securing devices.

**2.2.3** Annual surveys of the fixed and portable securing devices are the responsibility of the ship owner and the relevant entries into the records shall be confirmed by PRS Surveyor who also checks validity of the portable securing devices' certificates.

**2.2.4** Class renewal surveys and occasional surveys of the fixed and portable securing devices are carried out by the PRS surveyor. At least 1% of each kind of the securing devices, but no fewer than 10 items, are subject to visual inspection. If there is a likelihood of strength loss resulting from corrosion and/or wear-and-tear, 0.5% of the securing devices shall be strength-tested.

**2.2.5** On PRS request, the securing devices' manufacturer shall submit the relevant material certificates necessary to identify the material used in production of those devices.

## 2.3 Classification of Securing Devices and Specific Requirements

### 2.3.1 Container Securing Devices


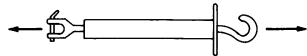
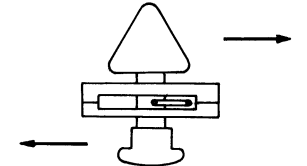
**2.3.1.1** The basic devices to be used for securing of containers are: lashing rods, lashing chains, twistlocks, bridge fittings, stowage cones, stacking cones, deck sockets and lashing points, turnbuckles, etc.

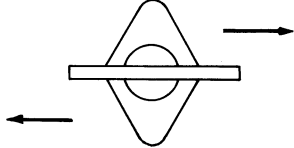
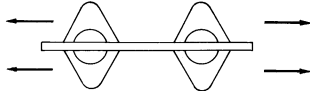
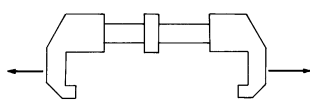
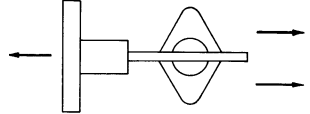
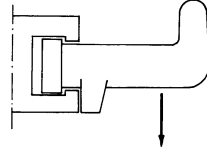
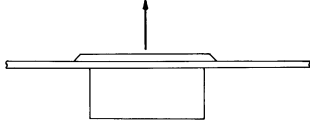
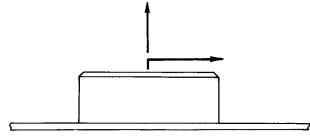
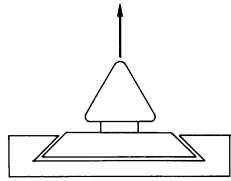
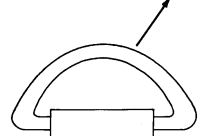
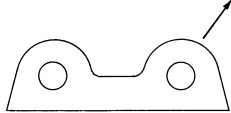
**2.3.1.2** All securing devices shall be properly marked to enable their identification against the relevant documents issued by the manufacturer or PRS.

**2.3.1.3** All the products tested and examined by the PRS surveyor shall be marked with a PRS stamp.

**2.3.1.4** Proof loads, Maximum Securing Loads and application of the test load to the essential securing devices are given in Table 2.3.1.4.

**Table 2.3.1.4**  
**Load application and load values for specific securing devices**

Item No.	Device	Test load application	Proof load	MSL	Notes
1	Lashing rod		1.1 MSL*	0.5 BL	
	Lashing chain		1.1 MSL	0.5 BL	
2	Turnbuckle *		1.1 MSL	0.5 BL	
3	Twistlock *		1.1 MSL	0.5 BL	Not less, however, than 250 kN

Item No.	Device	Test load application	Proof load	MSL	Notes
4	Single stacker		1.2 MSL	0.5 BL	
5	Double stacker		1.2 MSL	0.5 BL	
6	Bridge fitting *		250 kN	0.5 BL	Together with side fitting or corner fitting
7	Side fitting *		1.2 MSL	0.5 BL	Together with side socket
8	Penguin hook		1.1 MSL	0.5 BL	
9	Flush type deck fitting		1.2 MSL	0.5 BL	
10	Raised deck socket		1.2 MSL	0.5 BL	
11	Dovetail type socket		1.2 MSL	0.5 BL	
12	"D-ring"		1.2 MSL	0.5 BL	
13	Lashing plate		1.2 MSL	0.5 BL	

BL – breaking load

\* – to be checked in operation after the test has been complete



**2.3.1.5** Around 2% of the products out of each batch submitted for approval shall be tested. Where the batch size is smaller than 50 items, at least one item shall be tested.

**2.3.1.6** At least 2 to 5 per cent of the products out of each batch submitted for approval shall be checked in respect of workmanship and maintaining the allowable tolerances.

### **2.3.1.7 Materials and Welding**

**2.3.1.7.1** The securing devices shall fulfil the requirements of Chapters 12 and 13 of *Part IX – Materials and Welding* and they shall be made of:

- .1 normal-strength rolled steel of  $R_e$  min = 235 MPa,
- .2 forged steel or – in the case of bars – equivalent rolled steel of  $R_m$  min = 400 MPa,
- .3 higher-strength rolled steel of  $R_e$  min = 355 MPa,
- .4 cast steel of  $R_m$  min = 400 MPa.

**2.3.1.7.2** Carbon content (on the base of ladle analysis) in forgings and castings which are intended to be welded shall not exceed:

- .1 0.22% for steel forgings,
- .2 0.23% for cast steel forgings.

**2.3.1.7.3** Application of materials other than those specified in 2.3.1.9.1 is subject to PRS consideration in each particular case.

**2.3.1.7.4** Any procedure of welding of the securing devices is subject to PRS agreement in each particular case, and the welding consumables shall be approved by PRS.

**2.3.1.7.5** Welding shall be performed by welders authorised by PRS.

### **2.3.2 Securing Devices for Road Vehicles and Roll-trailers**

**2.3.2.1** The basic securing devices for road vehicles and roll-trailers are: lashing chains, tensioners, turnbuckles, web lashings, stanchions and support benches.

**2.3.2.2** Lashing chains, turnbuckles, tensioners, deck sockets and deck lashing points intended for securing of road vehicles and roll-trailers shall fulfil the requirements specified in 2.3.1.2, 2.3.1.3, 2.3.1.4, 2.3.1.5, 2.3.1.6, and 2.3.1.7. The maximum securing load (MSL) of lashings shall not be less than 100 kN, and they shall be made of material having suitable elongation characteristics.

**2.3.2.3** Lashings shall be attached to the securing points with hooks or other devices so designed that they cannot disengage from the aperture of the securing point if the lashing slackens during the voyage.

**2.3.2.4** Lashings shall be so designed and attached that it is possible to tighten them if they become slack.

**2.3.2.5** If there are securing devices of the same type and different strength characteristics and purpose, they shall be properly marked to avoid their mistaken application for the lashing of road vehicles and roll-trailers.

**2.3.2.6** Each web lashing shall consist of a tensioning device or a tension retaining device and flat woven textile webbing with end fittings for attachment to the vehicle elements and to the deck lashing points. Flat woven textile webbing shall be made as conventional or shuttleless woven narrow fabric. A characteristic of webbing is its narrow selvedge.

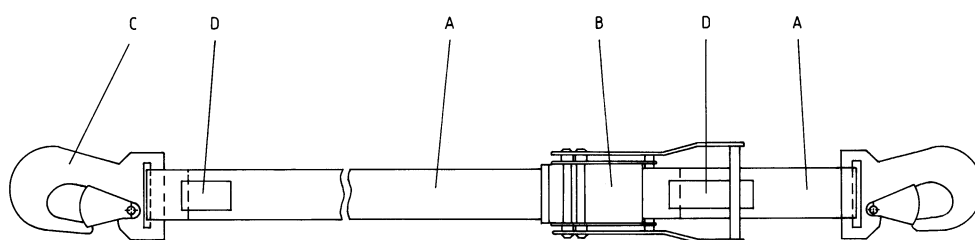


Fig. 2.3.2.6

Example of a web lashing for cars: A – flat woven textile webbing, B – ratchet tensioner, C – hook or other end fitting, D – marking (label).

**2.3.2.7** Tensioning devices, hooks and end fittings shall have no sharp edges or burrs which might damage the flat woven textile webbing.

**2.3.2.8** The textile webbing shall be produced wholly from high tenacity yarns fast to ultraviolet radiation and heat stabilised (to keep the strength properties within a range of  $-40\text{ }^{\circ}\text{C}$  to  $+70\text{ }^{\circ}\text{C}$ ) from the following materials: polyamide (high tenacity continuous multifilament), polyester (high tenacity continuous multifilament) or polypropylene (high tenacity continuous multifilament).

**2.3.2.9** Tensioning devices for the web lashing intended for lashing of cars shall be so designed as to exclude an unintentional release of the tension in the lashing. Tensioning devices based upon winch principles shall be designed in such a way that after  $2\frac{1}{4}$  turns around the slotted pin, the loose end does not slide out.

**2.3.2.10** Each complete web lashing intended for lashing of cars shall be marked with at least the following information:

- safe working load or maximum securing load,
- length in metre,
- material of the textile webbing,
- manufacturer's name,
- year of manufacture,
- warning: "Not for lifting!".

End fittings, tensioning devices, and tension indicator (where applied) shall be marked with at least the manufacturer's name. The web lashing marking shall be situated as shown in Fig. 2.3.2.6.

### 2.3.3 Securing Devices for Timber Deck Cargo

**2.3.3.1** The basic securing devices for timber deck cargo lashing shall be: lashings, stanchions, shackles, deck sockets and deck lashing points, tensioning devices, etc.

**2.3.3.2** Each securing device for timber deck cargo lashing shall be tested and marked so as to identify it against the relevant documents issued either by the manufacturer or by PRS.

**2.3.3.3** Each securing device for timber deck cargo lashing shall:

- .1 have breaking strength not less than 133 kN,
- .2 show the elongation not more than 5% after pretension with the load up to 80% of its breaking load,
- .3 not show plastic strain after the test load not less than 40% of its breaking load.

**2.3.3.4** Each lashing shall be equipped with a tensioning device or a system of tensioning devices situated so as to operate them safely. The tension caused by such a device or system shall not be less than:

- .1 27 kN in its horizontal part,
- .2 16 kN in its vertical part.

**2.3.3.5** The devices for quick release of the cargo shall be designed to exclude an unintentional release of the tension in the lashing.

**2.3.3.6** Stanchions (uprights) for securing timber deck cargo shall be made from steel and their construction shall be strong enough taking into account the size of timber deck cargo and how its lashing are fixed.

Strength calculations for stanchions shall be performed in accordance with Chapter 7 of *Code of Safe Practice for Ships Carrying Timber Deck Cargoes* (IMO Resolution A. 1048(27)).

The connection of stanchions to the deck or hatch shall be to the satisfaction of the Administration.

### **3 STOWAGE AND LASHING OF CONTAINERS**

#### **3.1 Application**

**3.1.1** This Chapter applies only to containers whose dimensions and weight meet the requirements of ISO 668. Carriage of other containers on board ships is subject to consideration by PRS in each particular case.

**3.1.2** The requirements of this Chapter apply to the ships assigned with the additional marks such as **CONTAINER SHIP** and **ACC**.

#### **3.2 Definitions**

**3.2.1** *Bay of containers* – containers stowed so that their side walls face each other leaving an adequate clearance between them.

**3.2.2** *Row of containers* – containers placed one after the other so that their door ends face each other leaving an adequate clearance between them.

**3.2.3** *Tier of containers* – containers arranged on the same level in bays and/or rows.

**3.2.4** *Stack of containers* – containers stacked one above the other.

**3.2.5** *Block of containers* – tier or tiers of containers connected with each other by means of the container stowage and lashing equipment.

#### **3.3 Stowage of Containers on Board Ships**

**3.3.1** All types and kinds of containers shall be so stowed that their longitudinal planes of symmetry are parallel to the ship's plane of symmetry. Other stowage is subject to consideration by PRS in each particular case.

**3.3.2** Containers shall be so stowed as to leave a passage enabling easy access to the compartments and equipment for essential services (e.g. fire extinguishers, CO<sub>2</sub> stations, fire hydrants, sounding pipes, switchboards etc.) as well as to enable access to container lashing equipment for easy control and maintenance.



**3.3.3** Containers stowed singly or in one row, may be stacked in two tiers only. Stacking of containers in more tiers is subject to consideration by PRS in each particular case.

**3.3.4** Where the bottom corner fittings of one side wall of a container rest on the hatch cover that changes its position during the ship motion and the corner fittings of the other side wall rest on special pillars, or where one couple of the bottom corner fittings rests on a hatch cover that changes its position during the ship motion whereas the other couple rests on another cover, such a container shall be suitably protected against the forces resulting from the possible movement of the hatch cover.

**3.3.5** It is recommended that containers be stowed on a deck so that their door ends face the stern. If, in place of a 40' container, two 20' containers are stowed, it is recommended that their door ends face the inside of a stack.

**3.3.6** Ships which are specifically designed and fitted for the purpose of carrying containers shall be provided with an approved Cargo Safe Access Plan (CSAP) on board, for all areas where containers are secured in order to demonstrate that personnel will have safe access for container securing operations (refer to Annex 3 to this Publication).

### **3.4 Lashing of Containers**

#### **3.4.1 General Indications**

**3.4.1.1** The lashing of containers may be done by means of: twistlocks, bridge fittings, lashings (chains and rods), special lashing pads, wedges, spacers, etc. Apart from the aforementioned container lashing equipment, special permanent or detachable structures (e.g. container lashing frames, free-standing cell guides, holds above the deck) may be used. Such structures and their connection with the hull shall fulfil the requirements specified in Part III – Hull Equipment.

**3.4.1.2** Containers shall be so attached that the forces in the container frames, lashing equipment and securing devices do not exceed the allowable values specified in 3.7.

**3.4.1.3** Containers stowed on the deck exposed to flooding shall be attached to permanent elements of the ship structure by means of twistlocks and lashings. While calculating the strength of these twistlocks or lashings, the buoyancy force acting on a container submerged to half of its height shall be taken into account.

**3.4.1.4** Containers stowed 0.25 *L* from the forward perpendicular, shall be properly attached taking into account the additional forces induced by the wave impact and shipping green seas, unless the containers are adequately protected by breakwaters or a similar structure.

**3.4.1.5** Lashing position design (platforms, bridges and other means plus their fencing) for container ships shall be in accordance with Annex 3 to this Publication.

#### **3.4.2 On-deck Lashing of Containers**

##### **3.4.2.1 Lashing of Containers in One Tier**

**3.4.2.1.1** Bottom corner fittings of the containers carried on deck in one tier shall be locked to the stowage bottom sockets with twistlocks or similar fittings, provided the forces in container frames do not exceed the values specified in 3.7.

Where there is no possibility of locking all the bottom corner fittings with twistlocks, the lashing pattern is subject to consideration by PRS in each particular case.

**3.4.2.1.2** Containers carried in one tier without twistlocks shall be placed on stowage cones and secured by lashings.

### **3.4.2.2 Lashing of Containers in Several Tiers**

**3.4.2.2.1** The lower tier of containers carried in several tiers shall be attached to the stowage bottom sockets in accordance with 3.4.2.1.

**3.4.2.2.2** The upper corner fittings of each tier (except for the top tier) and the bottom corner fittings of the next tier shall be locked by means of twistlocks. It is recommended that the upper corner fittings of the top tier be connected by means of bridge fittings.

**3.4.2.2.3** Where the forces in the frames of containers carried in several tiers exceed the allowable value, extra lashings shall be used for the containers in each stack in addition to the securing methods specified in 3.4.2.2.1 and 3.4.2.2.2. The number of lashings securing a stack of containers depends on the conditions specified in 3.5.2.

**3.4.2.2.4** Where containers are carried in two tiers, they may be secured without twistlocks. In that case lashings (instead of locking devices) shall be used in addition to stacking cones.

**3.4.2.2.5** Where containers are stowed in rows and the distance between the centres of the lower holes of the lower corner fittings of the adjacent containers is 280 mm (e.g. two 20' containers in place of one 40' container), the adjacent containers in a row shall be connected by means of stacking cones and bridge fittings.

When it is evident from calculations that the allowable forces in the frames of adjacent containers are exceeded, additional lashings shall be used to prevent transverse displacement of a block of containers.

### **3.4.3 Lashing of Containers in Ship Holds**

#### **3.4.3.1 Lashing of Containers in Holds without Cell Guides**

**3.4.3.1.1** Containers stowed in holds in one two or three tiers may be secured by means of locking devices and/or lashings as containers on deck.

**3.4.3.1.2** Containers stowed in holds in more than three tiers or containers that are not secured by means of locking devices and/or lashings (block of containers) shall be secured with special fittings, wedges, supports, etc.

**3.4.3.1.3** Special fittings, wedges, supports, etc. shall be fitted to or secured by the permanent hull elements (e.g. hatch coaming, web frame) of adequate strength.

**3.4.3.1.4** Containers shall be supported or secured at the corner fittings, and the direction of the support reactive forces shall be close to athwartship.

**3.4.3.1.5** The number of the special fittings, wedges, supports and other things securing a block of containers and their lay-out shall so decided that the forces in the frames of containers do not exceed the allowable values specified in 3.7.

### 3.4.3.2 Lashing of Containers in Holds with Cell Guides

**3.4.3.2.1** Containers stowed in six or more tiers shall be stowed in cell guides forming a cell of containers.

**3.4.3.2.2** The structure of the guides shall fulfil the requirements specified in *Part III – Hull Equipment*.

## 3.5 Calculations of Container Lashings

### 3.5.1 Symbols

The following symbols have been introduced in this Chapter:

$a$  – number of the container in stack (from 1 to  $n$ );

$a_l$  – resultant longitudinal acceleration of container, [m/s<sup>2</sup>] (see 3.5.2.2);

$a_t$  – resultant transverse acceleration of container, [m/s<sup>2</sup>] (see 3.5.2.2);

$a_v$  – resultant vertical acceleration of container, [m/s<sup>2</sup>] (see 3.5.2.2);

$b_s$  – distance between container supports, [mm];

$g_o$  – acceleration of gravity, 9.81 m/s<sup>2</sup>;

$h$  – container height, [mm];

$i, j, k, \dots, m$  – symbols of certain levels representing the number of containers stowed below;

$K_c$  – racking stiffness of container wall, [kN/mm];

$K_c = 10.0$  for doorless end;

$K_c = 3.85$  for door end;

$K_i, K_j, K_k, K_m$  – horizontal stiffness of lashing on levels  $i, j, k, m$ , respectively, [kN/m]

$l_i$  – active length of lashing, [mm];

$M$  – maximum weight of single container, where constant for the whole block or stack, [t];

$M_a$  – maximum weight of single container, where different for each tier in block or in stack, [t];

$n$  – number of containers in stack;

$P_c$  – maximum vertical force compressing corner posts of the container in the lowest tier, [kN];

$P_h$  – horizontal force acting on a container frame when the weight of each container is constant, [kN];

$P_{ha}$  – horizontal force acting on a container frame when the weight of the stowed containers varies in tiers within a stack, [kN];

$P_{li}$  – longitudinal force in a lashing (at level  $i$ ), [kN];

$P_{ri}$  – horizontal reactive force in lashing and supporting arrangements (at level  $i$ ), [kN];

$P_{sh}$  – vertical reactive force in stowage bottom sockets, [kN];

$P_w$  – wind force acting on containers stowed on deck, [kN];

$P_w = 18.5$  for 20' containers, [kN];

$P_w = 37.0$  for 40' containers, [kN];

$P_w = 8.0$  for end walls of 20' and 40' containers, [kN];

$S_r$  – vertical force in the top side girder or header of a container in the lowest tier, [kN];

$\alpha$  – coefficient of container frame horizontal strain:

$\alpha = 0.5$  for doorless and door ends;

$\alpha = 0$  for side wall;

$\beta$  – angle between lashing and vertical line, [deg];

$\delta_{ic}$  – clearance between a container and rigid support (at level  $i$ ), [mm];

$\delta_{io}$  – free displacement of a container stack (at level  $i$ ), [mm];

$\varphi$  – roll angle, [rad].

### 3.5.2 Calculation of Forces in Lashing System

**3.5.2.1** The forces acting in the lashing system are caused by the acceleration of gravity, the accelerations resulting from the ship motion, wind pressure and also from the elastic strain of the container frames as well as the lashing equipment. The distribution of forces is shown in Fig. 3.5.2.1.

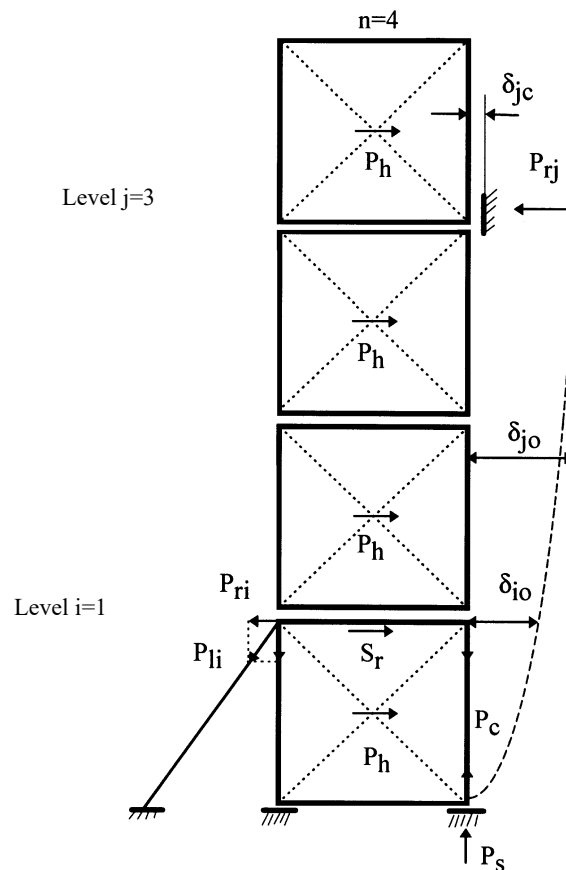


Fig. 3.5.2.1

Distribution of forces in a container stack and in lashings

**3.5.2.2** The accelerations mentioned in 3.5.2.1 shall be calculated using Part II – Hull.

**3.5.2.3** To determine and calculate the forces, the following assumptions have been made:

- .1 the bending stiffness of a container walls is many times as much as their shear stiffness. The container walls are considered to be shear plates;
- .2 the internal clearances in the arrangements connecting the container tiers are neglected;
- .3 a container and lashings are made from the material of linear elasticity;
- .4 initial stresses in lashings are neglected;
- .5 the containers are homogeneously loaded with the centre of gravity in the geometric centre point of a container and the resultant forces induced by the accelerations are applied in those centres.

**3.5.2.4** The horizontal force  $P_h$  (see Fig. 3.5.2.4) or  $P_{ha}$  acting on a container frame is induced by the accelerations resulting from the ship motion on waves, and by the wind pressure exerted on the containers stowed at the weather side of a ship. The horizontal forces shall be calculated using the following formulae:

$$P_h = 0.5 (M a_h + P_w), \quad [\text{kN}] \quad - \quad \text{where the mass of containers in a stack is constant} \quad (3.5.2.4-1)$$

$$P_{ha} = 0.5 (M_a a_h + P_w), \quad [\text{kN}] \quad - \quad \text{where the mass of containers in a stack is variable} \quad (3.5.2.4-2)$$

$a_h$  – vertical components,  $a_t$  or  $a_l$ , of container acceleration.

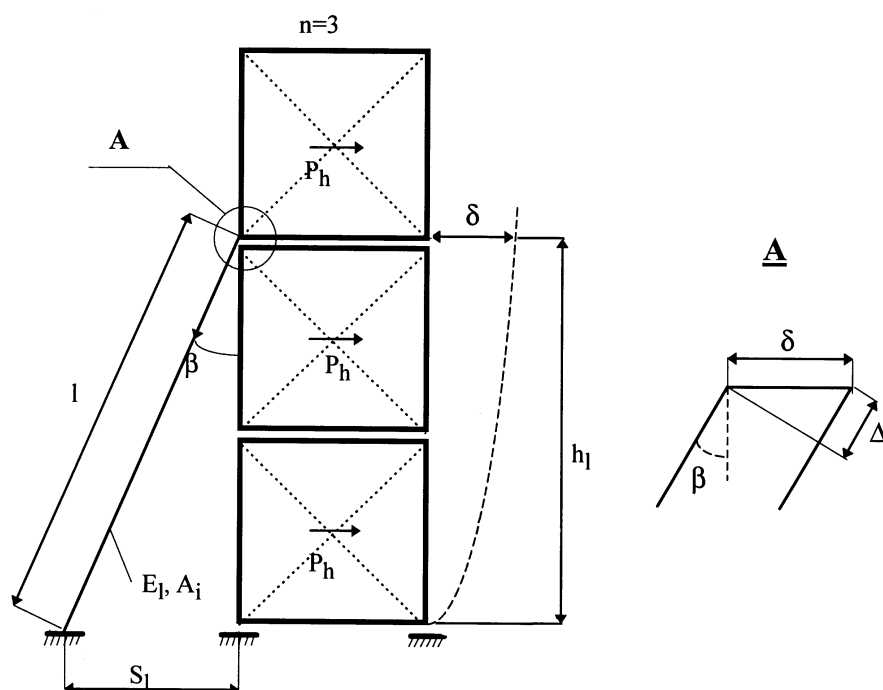


Fig. 3.5.2.4 Deformation of container stack due to accelerations and wind force

**3.5.2.5** The horizontal forces acting transversely  $P_{ht}$  or longitudinally  $P_{hl}$  shall be calculated substituting  $a_t$  or  $a_l$  for  $a_h$  in formulae 3.5.2.4-1 and 3.5.2.4-2 respectively.

**3.5.2.6** The horizontal reactive force  $P_r$  in the arrangements lashing and supporting the stack or block of containers is due to the action of forces  $P_h$  or  $P_{ha}$  on container frames. The procedure of calculation of  $P_r$  force is specified in 3.5.3.



**3.5.2.7** The horizontal force  $S_r$  (it may act along the header  $S_{rt}$  or top side rail  $S_{rl}$ ) acting in the upper member of the lowest container in the stack is induced by the horizontal forces  $P_h$  or  $P_{ha}$  acting on the frames of containers stowed over the lowest tier and the partial forces ( $\alpha P_h$  or  $\alpha P_{ha}$ ) of the lowest tier as well as by the horizontal lashing and support forces  $P_r$ .

The horizontal force  $S_r$  shall be calculated using the following formulae:

$$S_r = (n - 1 + \alpha)P_h - \Sigma P_r, \quad [\text{kN}] \quad \text{-- where } P_h = \text{const.} \quad (3.5.2.7-1)$$

$$S_r = \sum_{a=2}^n P_{ha} + \alpha P_{h1} - \Sigma P_r, \quad [\text{kN}] \quad \text{-- where } P_{ha} \text{ is variable} \quad (3.5.2.7-2)$$

$P_{h1}$  – horizontal force acting on a frame of the lowest container in a stack [kN].

**3.5.2.8** The horizontal force  $S_r$  calculated from formula 3.5.2.7-1 or 3.5.2.7-2 shall not exceed the allowable values specified in 3.7.

**3.5.2.9** The maximum vertical reactive forces  $P_{sc}$  and  $P_{st}$  in the stowage bottom sockets are induced by the acceleration of gravity and the accelerations caused by the ship motion – on waves – on the containers in a stack or block.

The maximum vertical reactive forces  $P_{sc}$  and  $P_{st}$  acting on a stowage socket shall be calculated using the following formulae:

– on the compression side:

$$P_{sc} = 0.25 n M g_o + P_{sh} + \Sigma P_{sl}, \quad [\text{kN}], \text{ or} \quad (3.5.2.9-1)$$

$$P_{sc} = 0.25 n M (g_o + a_v), \quad [\text{kN}] \quad (3.5.2.9-2)$$

whichever is greater;

– on the tension side:

$$P_{st} = 0.25 n M g_o \cos \varphi - P_{sh} + \Sigma P_{sl}, \quad [\text{kN}] \quad (3.5.2.9-3)$$

$P_{sl}$  – vertical component of lashing force;

$P_{sh}$  – see formula 3.5.4-1.

Where  $P_{st}$ , proves negative, twistlocks shall be used.

$P_{sl}$  force is considerable on the compression side when cross-lashings are used. When side lashings are used,  $P_{sl}$  force is considerable on the tension side.

In the case of a container mass variable in a stack, the expression  $nM$  shall be replaced by the sum

$$\sum_{a=1}^n M_a.$$

**3.5.2.10** The maximum vertical force  $P_c$  compressing the corner posts of the lowest container in a stack is induced by the acceleration of gravity and the accelerations caused by the ship motion – on waves – on the containers stowed above the first tier in a stack.

The maximum vertical force compressing the corner post shall be taken as the maximum of the values calculated using the following formulae:

$$P_c = 0.25 (n - 1) M (g_o + a_v), \quad [\text{kN}], \text{ or} \quad (3.5.2.10-1)$$

$$P_c = 0.25 (n - 1) M g_o + P_{ch} + \Sigma P_{sl}, \quad [\text{kN}] \quad (3.5.2.10-2)$$

In the case of a container mass variable in a stack, the expression  $(n - 1) M$  shall be replaced by  $\sum_{a=2}^n M_a$  in the above formulae, whereas  $P_{ch}$  shall be calculated using formula 3.5.5-1.

**3.5.2.11** The vertical component of lashing force  $P_{sl}$  shall be calculated using one of the following formulae:

$$P_{sl} = P_l \cos \beta, \quad [\text{kN}], \text{ or} \quad (3.5.2.11-1)$$

$$P_{sl} = P_r \frac{h_l}{S_l}, \quad [\text{kN}] \quad (3.5.2.11-2)$$

$h_l$  and  $S_l$  – see Fig. 3.5.2.4.

**3.5.2.12** The lashing force  $P_l$  is induced by the forces  $P_h$  acting on the frames of the containers in a stack or block and it depends on the horizontal stiffness  $K$  of the container lashing and on the stack displacement  $\delta$ .

The horizontal stiffness  $K$  of the container lashing is defined as the ratio of the horizontal force causing the container displacement  $\delta$  to this displacement.

According to Fig. 3.5.2.4,  $K$  shall be calculated using the following formula:

$$K = \frac{E_l A_l \sin^2 \beta}{l_l}, \quad [\text{kN/mm}], \quad (3.5.2.12)$$

$E_l$  – modulus of elasticity of a lashing,  $[\text{kN/mm}^2]$ ;

$E_l = 75$  for wire lashings,

$E_l = 100$  for chain lashings,

$E_l = 0.04 (l_c - 1000)$  for lashing rods,

$A_l$  – cross section area of lashing,  $[\text{mm}^2]$ ; the value of  $A_l$  shall be calculated for:

- nominal diameter – wire lashings,
- link bar diameter – chain lashings,
- bar diameter – lashing rods.

**3.5.2.13** The lashing force  $P_l$  shall be calculated using the following formula:

$$P_l = \frac{\delta E_l A_l \sin \beta}{l_l}, \quad [\text{kN}], \quad (3.5.2.13)$$

$l_l$  – see Fig. 3.5.2.4.

### 3.5.3 Determination of Reactive Forces for Flexible and Rigid Lashings of Containers

#### 3.5.3.1 Flexible Lashing of Container Stack

**3.5.3.1.1** The container stack shown in Fig. 3.5.3.1 is secured by lashings on levels  $i, j, k, m$ .

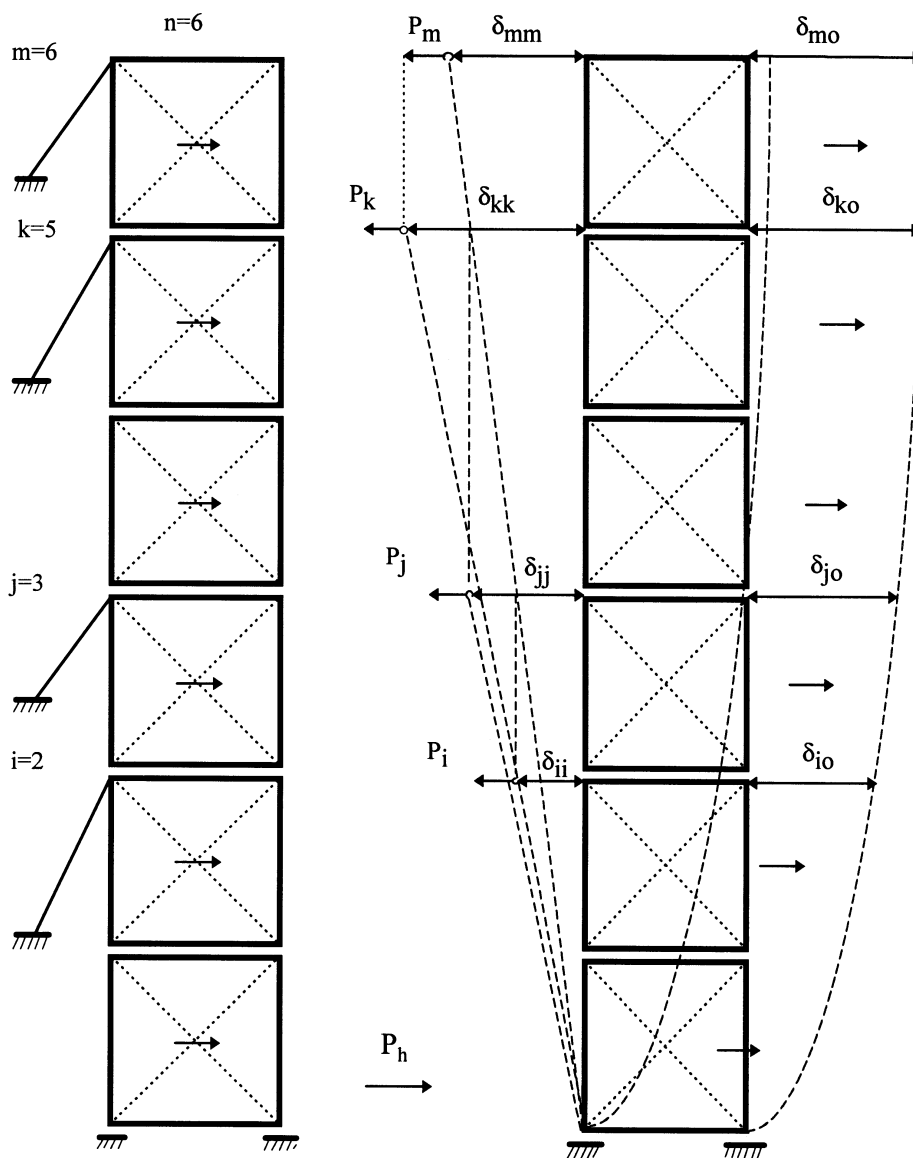


Fig. 3.5.3.1  
Flexible lashing of a container stack and reactive forces in a stack

Containers in a stack are subjected to:

- .1 uniform horizontal forces  $P_h$ , applied at the half height of containers;
- .2 variable horizontal forces  $P_{ha}$  ( $P_{h1}, P_{h2}, P_{h3}, \dots, P_{hn}$ ), applied at the half height of containers.

**3.5.3.1.2** Free horizontal displacements  $\delta_{io}, \delta_{jo}, \delta_{ko}, \delta_{mo}$  of a container stack at levels  $i, j, k, m$ , respectively caused by  $P_h$  forces shall be calculated using the following formula:

$$\delta_{io} = \frac{P_h}{K_c} \left[ \sum_{a=1}^i (n-a) + i\alpha \right] \quad (3.5.3.1.2-1)$$

for level  $i$  and similarly for levels  $j, k$  and  $m$ ,

$K_c$  – racking stiffness of a container wall, [kN/mm].

Free horizontal displacements  $\delta_{io}$ ,  $\delta_{jo}$ ,  $\delta_{ko}$ ,  $\delta_{mo}$  of a container stack at levels  $i, j, k, m$ , respectively caused by variable forces  $P_{ha}$  shall be calculated using the following formula:

$$\delta_{io} = \frac{1}{K_c} (\alpha \sum_{a=1}^i P_{ha} + \sum_{a=1}^i \sum_{b=a+1}^n P_{hb}) - \text{ for } i \text{ level and similarly for } j, k, m \text{ levels} \quad (3.5.3.1.2-2)$$

**3.5.3.1.3** The horizontal displacements caused by forces  $P_i, P_j, P_k, P_m$ , at specific levels shall be calculated using the following formulae:

$$\text{at level } i \quad \delta_{ii} = \frac{i P_i}{K_c}, \quad [\text{mm}] \quad (3.5.3.1.3-1)$$

$$\text{at level } j \quad \delta_{jj} = \frac{j P_j}{K_c}, \quad [\text{mm}] \quad (3.5.3.1.3-2)$$

$$\text{at level } k \quad \delta_{kk} = \frac{k P_k}{K_c}, \quad [\text{mm}] \quad (3.5.3.1.3-3)$$

$$\text{at level } m \quad \delta_{mm} = \frac{m P_m}{K_c}, \quad [\text{mm}] \quad (3.5.3.1.3-4)$$

At the levels below the acting force, displacement is proportional to the number of the respective level, e.g. the displacement of level  $i$  corresponding to the force acting at level  $k$  is:

$$\delta_{ik} = \frac{i}{k} \delta_{kk}, \quad [\text{mm}] \quad (3.5.3.1.3-5)$$

The displacement of level  $j$  corresponding to the force acting at level  $m$  is:

$$\delta_{jm} = \frac{j}{m} \delta_{mm}, \quad [\text{mm}] \quad (3.5.3.1.3-6)$$

**3.5.3.1.4** The horizontal component of the lashing reactive force is expressed as a function of displacement at the level of action of this force.

The reactive forces at levels  $i, j, k, m$  expressed as a function of displacements at these levels shall be calculated using the following formulae:

$$P_{ri} = K_i [\delta_{io} - (\delta_{im} + \delta_{ik} + \delta_{ij} + \delta_{ii})], \quad [\text{kN}] \quad (3.5.3.1.4-1)$$

$$P_{rj} = K_j [\delta_{jo} - (\delta_{jm} + \delta_{jk} + \delta_{jj} + \delta_{ii})] \quad [\text{kN}] \quad (3.5.3.1.4-2)$$

$$P_{rk} = K_k [\delta_{ko} - (\delta_{km} + \delta_{kk} + \delta_{jj} + \delta_{ii})], \quad [\text{kN}] \quad (3.5.3.1.4-3)$$

$$P_{rm} = K_m [\delta_{mo} - (\delta_{mm} + \delta_{kk} + \delta_{jj} + \delta_{ii})], \quad [\text{kN}]. \quad (3.5.3.1.4-4)$$

**3.5.3.1.5** The horizontal forces  $P_i, P_j, P_k, P_m$  mentioned in 3.5.3.1.3 are equal to the reactive forces defined in 3.5.3.1.4. After placement of the expressions specified in 3.5.3.1.3 in the equations given in 3.5.3.1.4, the following system of equations for calculation of the reactive forces of lashings is obtained:

$$\left(\frac{K_c}{K_m} + m\right)P_{rm} + kP_{rk} + jP_{rj} + iP_{ri} = \delta_{mo} K_c \quad (3.5.3.1.5-1)$$

$$kP_{rm} + \left(\frac{K_c}{K_k} + k\right)P_{rk} + jP_{rj} + iP_{ri} = \delta_{ko} K_c \quad (3.5.3.1.5-2)$$

$$jP_{rm} + jP_{rk} + \left(\frac{K_c}{K_j} + j\right)P_{rj} + iP_{ri} = \delta_{jo} K_c \quad (3.5.3.1.5-3)$$

$$iP_{rm} + iP_{rk} + iP_{rj} + \left(\frac{K_c}{K_i} + i\right)P_{ri} = \delta_{io} K_c \quad (3.5.3.1.5-4)$$

The above system of equations may be expressed in the matrix form:

$$\begin{vmatrix} \left(\frac{K_c}{K_m} + m\right) & k & j & i \\ k & \left(\frac{K_c}{K_k} + k\right) & j & i \\ j & j & \left(\frac{K_c}{K_j} + j\right) & i \\ i & i & i & \left(\frac{K_c}{K_i} + i\right) \end{vmatrix} \begin{vmatrix} P_{rm} \\ P_{rk} \\ P_{rj} \\ P_{ri} \end{vmatrix} = \begin{vmatrix} \delta_{mo} K_c \\ \delta_{ko} K_c \\ \delta_{jo} K_c \\ \delta_{io} K_c \end{vmatrix}$$

The matrix may be expanded or reduced depending on the number of lashings, e.g. for a system with two lashings the matrix is reduced to:

$$\begin{vmatrix} \left(\frac{K_c}{K_j} + j\right) & i \\ i & \left(\frac{K_c}{K_i} + i\right) \end{vmatrix} \begin{vmatrix} P_{rj} \\ P_{ri} \end{vmatrix} = \begin{vmatrix} \delta_{jo} K_c \\ \delta_{io} K_c \end{vmatrix}$$

### 3.5.3.2 Rigid Lashing of Container Stack

**3.5.3.2.1** A stack of containers shown in Fig. 3.5.3.2 has rigid supports at levels  $i, j, k, m$ . The containers are loaded with uniform horizontal  $P_h$ , acting on each frame or with variable forces  $P_{ha}$ .

The clearances between the containers and the rigid supports at all levels shall be such as to ensure the free displacement of a container stack equal to  $\delta_{ic}, \delta_{jc}, \delta_{kc}, \delta_{mc}$  respectively.

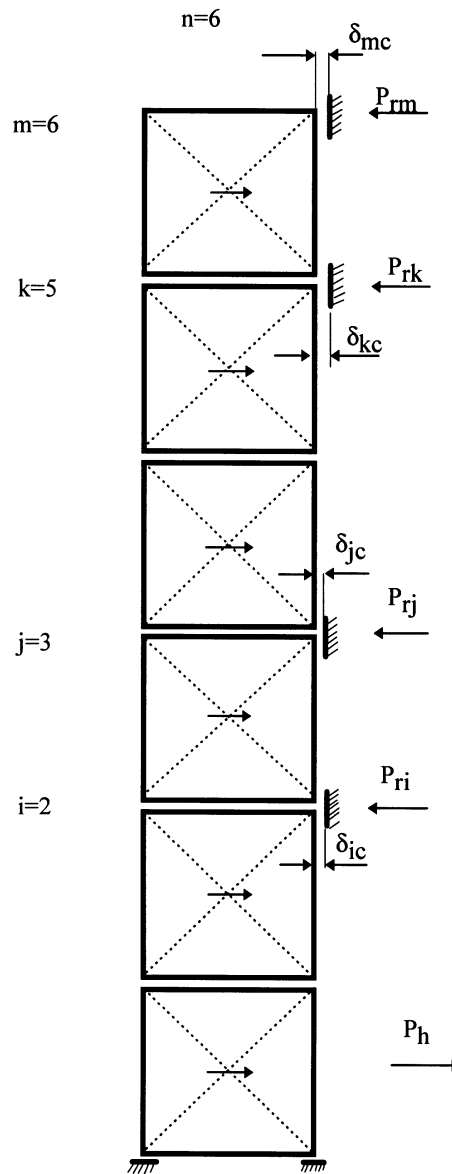


Fig. 3.5.3.2

Rigid lashing of a container stack and reactive forces in a stack

**3.5.3.2.2** After taking into account the clearances between the containers and the supports, the equations for the reactive forces given in 3.5.3.1.4 as functions of displacement at levels  $i, j, k, m$  are expressed as follows:

$$P_{ri} = K_i [\delta_{io} - \delta_{ic} - (\delta_{im} + \delta_{ik} + \delta_{ij} + \delta_{ii})], \quad [\text{kN}] \quad (3.5.3.2.2-1)$$

$$P_{rj} = K_j [\delta_{jo} - \delta_{jc} - (\delta_{jm} + \delta_{jk} + \delta_{jj} + \delta_{ii})], \quad [\text{kN}] \quad (3.5.3.2.2-2)$$

$$P_{rk} = K_k [\delta_{ko} - \delta_{kc} - (\delta_{km} + \delta_{kk} + \delta_{jj} + \delta_{ii})], \quad [\text{kN}] \quad (3.5.3.2.2-3)$$

$$P_{rm} = K_m [\delta_{mo} - \delta_{mc} - (\delta_{mm} + \delta_{kk} + \delta_{jj} + \delta_{ii})], \quad [\text{kN}] \quad (3.5.3.2.2-4)$$

After inserting the expressions given in 3.5.3.1.3 into the above equations and assuming that the stiffness of the supports  $K_i, K_j, K_k, K_m$  tends to infinity, the following is obtained:

$$\left(\frac{K_c}{K_i} + i\right) \rightarrow i, \quad (3.5.3.2.2-5)$$

$$\left(\frac{K_c}{K_j} + j\right) \rightarrow j, \quad (3.5.3.2.2-6)$$

$$\left(\frac{K_c}{K_k} + k\right) \rightarrow k, \quad (3.5.3.2.2-7)$$

$$\left(\frac{K_c}{K_m} + m\right) \rightarrow m, \quad (3.5.3.2.2-8)$$

The reactive forces in supports are determined by the following linear equations:

$$m P_{rm} + k P_{rk} + j P_{rj} + i P_{ri} = (\delta_{mo} - \delta_{mc})K_c \quad (3.5.3.2.2-9)$$

$$k P_{rm} + k P_{rk} + j P_{rj} + i P_{ri} = (\delta_{ko} - \delta_{kc})K_c \quad (3.5.3.2.2-10)$$

$$j P_{rm} + j P_{rk} + j P_{rj} + i P_{ri} = (\delta_{jo} - \delta_{jc})K_c \quad (3.5.3.2.2-11)$$

$$i P_{rm} + i P_{rk} + i P_{rj} + i P_{ri} = (\delta_{io} - \delta_{ic})K_c \quad (3.5.3.2.2-12)$$

The above system of equations takes the following matrix form:

$$\begin{vmatrix} m & k & j & i \\ k & k & j & i \\ j & j & j & i \\ i & i & i & i \end{vmatrix} \begin{vmatrix} P_{rm} \\ P_{rk} \\ P_{rj} \\ P_{ri} \end{vmatrix} = \begin{vmatrix} (\delta_{mo} - \delta_{mc})K_c \\ \delta_{ko}K_c \\ (\delta_{jo} - \delta_{jc})K_c \\ \delta_{io}K_c \end{vmatrix}$$

The matrix may be expanded or reduced depending on the number of supports.

### 3.5.3.3 Rigid and Flexible (Mixed) Lashing of Container Stack

**3.5.3.3.1** The stack of containers shown in Fig. 3.5.3.3 has flexible lashings at levels  $i$ ,  $k$  and rigid supports at levels  $j$ ,  $m$ . The containers are loaded with uniform forces  $P_h$  acting on each frame or with variable forces  $P_{ha}$ .

The stiffness of the lashings at levels  $i$ , and  $k$  is  $K_i$  i  $K_k$ , respectively, and the clearance between the containers and supports at levels  $j$ , and  $m$  is  $\delta_{jc}$  i  $\delta_{mc}$  respectively.

**3.5.3.3.2** Taking into account the flexible lashing of a container stack given in 3.5.3.1 and the rigid lashing of the container stack given in 3.5.3.2, the system of linear equations for the horizontal reactive forces is expressed in a matrix form by:

$$\begin{vmatrix} m & k & j & i \\ k & (\frac{K_c}{K_k} + k) & j & i \\ j & j & j & i \\ i & i & i & (\frac{K_c}{K_i} + i) \end{vmatrix} \begin{vmatrix} P_{rm} \\ P_{rk} \\ P_{rj} \\ P_{ri} \end{vmatrix} = \begin{vmatrix} (\delta_{mo} - \delta_{mc})K_c \\ \delta_{ko}K_c \\ (\delta_{jo} - \delta_{jc})K_c \\ \delta_{io}K_c \end{vmatrix}$$

### 3.5.4 Determination of Vertical Reactive Forces in Stowage Bottom Sockets

The vertical reactive force  $P_{sh}$  for the container stack shown in Fig. 3.5.3.3 shall be calculated using the following formula:

$$P_{sh} = \frac{h}{b_s} [f(P_{ha}) - (iP_{ri} + jP_{rj} + kP_{rk} + mP_{rm})], \text{ [kN]} \quad (3.5.4-1)$$

$f(P_{ha})$  represents the function:

$$f(P_{ha}) = 0.5 P_h n^2 - \text{for constant } P_{ha} \quad (3.5.4-2)$$

$$f(P_{ha}) = \sum_{a=1}^n (a - 0.5) P_{ha} - \text{for variable } P_{ha} \quad (3.5.4-3)$$

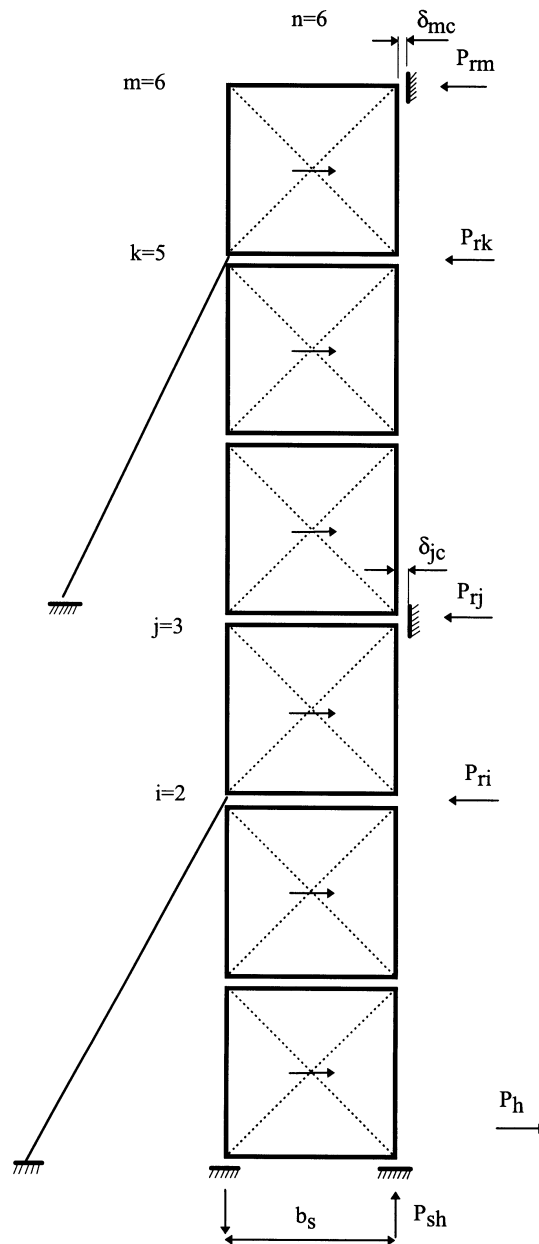


Fig. 3.5.3.3 Rigid and flexible lashing of container stack and reactive forces in stack



### 3.5.5 Determination of Components of the Maximum Compressive Force Acting on the Corner Post of the Lowest Container in a Stack

The compressive force  $P_{ch}$  shown in Fig. 3.5.5 acting on a corner post of the lowest container in a stack, due to the forces  $P_{h1}$ , shall be determined using the following formula:

$$P_{ch} = P_{sh} - \frac{P_{h1} h}{2b_s}, \quad [\text{kN}] \quad (3.5.5-1)$$

$P_{h1}$  – horizontal force acting on the frame of the lowest container, [kN].

### 3.5.6 Formulae and Calculation Examples

**3.5.6.1** Formulae for calculation of horizontal and vertical supporting forces for typical cases of lashing of container stacks are given in Annex 1.

**3.5.6.2** Calculation examples are given in Annex 2.

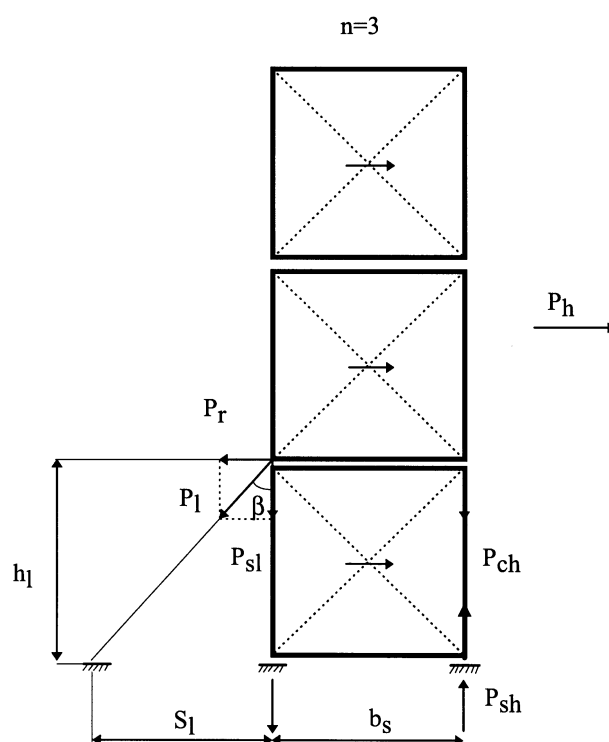


Fig. 3.5.5  
Reactive forces in container a stack

## 3.6 Lashing of Blocks of Containers

**3.6.1** Container stacks transversely connected by stacking cones and bridge fittings form a block of containers. Blocks of containers may be secured by lashings or supported. The clearance in stacking cones and bridge fittings are normally neglected. The block of containers shall be calculated on the base of analysis of single stacks of the same displacement. The resulting horizontal reactive force is, in general, the sum of all reactive forces from individual stacks.

**3.6.2** The horizontal reactive force of the rigid lashing of containers in a block of containers where clearance  $\delta_b$  occurs in each horizontal connection of stacks shall be determined for each stack in accordance with 3.5.3.2.

For each container stack  $\delta_{ic}$ ,  $\delta_{jc}$ ,  $\delta_{kc}$ ,  $\delta_{mc}$ , the clearances shall be increased by  $\delta_b$ , which occurs in the connection of stacks.

The reactive forces of the rigid lashing at each level are the sum of all the reactive forces in each stack.

**3.6.3** Where a block of containers is secured on both sides by rigid lashing subject to compression and tension and there is no clearance between the particular connections, the supporting load may be divided into two equal parts per one lashing.

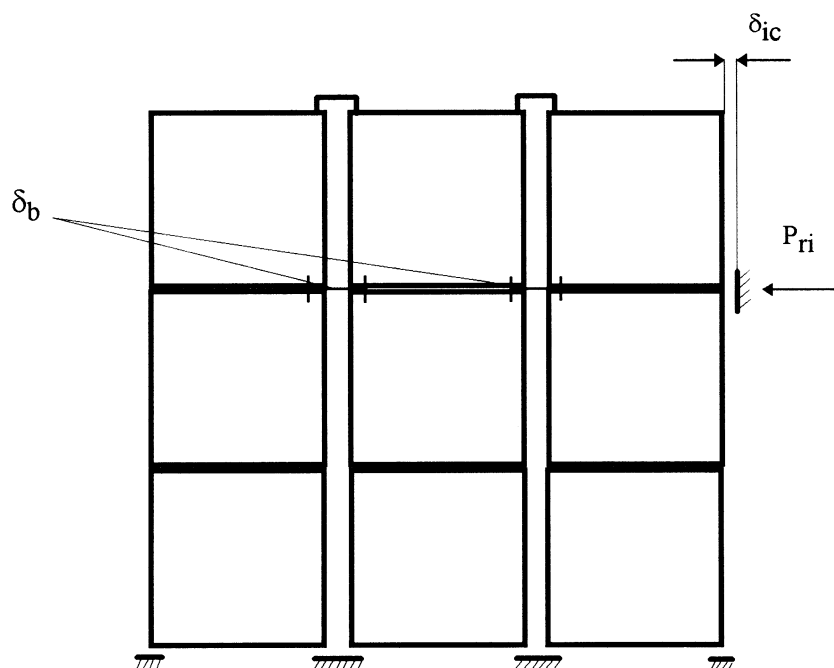


Fig. 3.6 Block of containers

### 3.7 Permissible Forces and Safety Factors for Containers, Lashings and Similar Devices

#### 3.7.1 Forces Acting in Container and on Container

**3.7.1.1** The permissible forces in the container and in the lashing system are given in Table 3.7.1.1.

**3.7.1.2** Where containers with gross mass, stacking strength and stiffness greater than commonly used, the forces acting on the containers in a lashing system may be greater than specified in 3.7.1.1.

In that case, an increase of the allowable forces is subject to PRS agreement in each particular case.

**Table 3.7.1.1**  
**Allowable forces acting in a container and on a container**

Kinds of forces	Values of forces, [kN], for	
	20' containers	40' containers
Racking forces of: – door and doorless ends $S_r$ – side wall $S_r$	150 75	150 75
Vertical reactive force in stowage bottom socket $P_{sc}$	715	950
Corner compressing force (vertical) $P_c$	635	845
Corner tensile force (vertical)	100	150
Corner fittings load exerted by lashings: – horizontal force $P_r$ – vertical force $P_{sl}$	150 300	150 300
Vertical tension in bottom corner fitting	200	250
Horizontal forces supporting corner fittings (perpendicular to container side walls): – bottom corner fitting – tension – bottom corner fitting – compression – top corner fitting – tension – top corner fitting – compression	200 300 200 200	250 350 250 250

### 3.8 Container Stack Securing against Separation from the Base

#### 3.8.1 General

Container stacks without the devices locking them to deck may be subject to tipping, i.e. some of the corners may separate from the base. The horizontal supports and lashings will be subjected to additional forces which shall be taken into account while selecting the securing devices. Calculation patterns are given in 3.8.2, 3.8.3 and 3.8.4.

#### 3.8.2 Container Stack with Single Rigid or Flexible Lashing

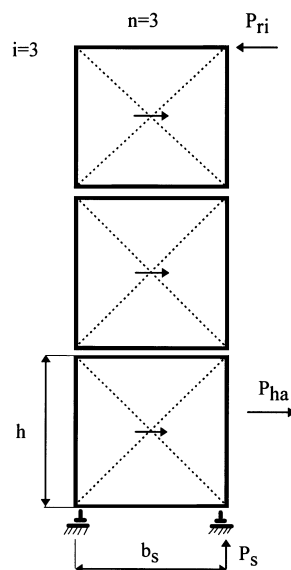


Fig. 3.8.2.1 Single stack of containers in case of tipping

**3.8.2.1** The stack in question is secured as shown in Fig. 3.8.2.1.

The horizontal supporting force is determined by:

$$P_{ri} = \frac{f(P_{ha})h - 0.5f(M_a)g_o b_s}{S}, \quad [\text{kN}] \quad (3.8.2.1)$$

$$f(P_{ha}) = 0.5P_h n^2 \quad - \text{ where } P_h \text{ is constant,}$$

$$f(P_{ha}) = \sum_{a=1}^n (a - 0.5)P_{ha} \quad - \text{ where } P_{ha} \text{ is variable,}$$

$$f(M_a) = 0.5nM \quad - \text{ where } M \text{ is constant,}$$

$$f(M_a) = 0.5 \sum_{a=1}^n M_a \quad - \text{ where } M_a \text{ is variable,}$$

$S = ih$  – for rigid lashing or cross-lashing,

$$S = ih + \frac{b_s}{\text{tg } \beta} \quad - \text{ for external lashing.}$$

**3.8.2.2** The maximum vertical supporting force is determined by:

$$P_s = f(M_a)g_o + P_{sl}, \quad [\text{kN}] \quad (3.8.2.2)$$

$P_{sl}$  – vertical component of lashing force, [kN]

### 3.8.3 Container Stack with Several Horizontal Supports where Top Support is Rigid

**3.8.3.1** The subject stack of containers is shown in Fig. 3.5.3.3. The top support is rigid while the others are rigid or flexible.

**3.8.3.2** The horizontal supporting forces  $P_{ri}$ ,  $P_{rj}$ ,  $P_{rk}$ ,  $P_{rm}$  and the vertical supporting force  $P_{sh}$  are calculated in accordance with 3.5.3.3 and 3.5.4.

**3.8.3.3** When tipping of the container stack occurs, the horizontal force shall be increased by the value calculated using the following formula:

$$P'_{rm} = P_{rm} + [P_{sh} - 0.5f(M_a)g_o] \frac{b_s}{mh}, \quad [\text{kN}] \quad (3.8.3.3)$$

$f(M_a)$  – in accordance with 3.8.2.1.

**3.8.3.4** The maximum vertical supporting force is determined by:

$$P_s = f(M_a)g_o + \sum P_{sl}, \quad [\text{kN}] \quad (3.8.3.4)$$

$\sum P_{sl}$  – sum of vertical components of lashing forces.

**3.8.3.5** The formula given in 3.8.3.3 is valid for any number of the stack supports greater than 1. In any case the index may be replaced by the corresponding index of the top rigid support.

### 3.8.4 Container Stack with Several Flexible Lashings

**3.8.4.1** The below calculations are valid for the systems with four flexible lashings shown in Fig. 3.5.3.1.

**3.8.4.2** The horizontal supporting forces  $P_{ri}$ ,  $P_{rj}$ ,  $P_{rk}$ ,  $P_{rm}$  and the vertical supporting force  $P_{sh}$  are calculated in accordance with 3.5.3.1.

**3.8.4.3** When tipping occurs, the horizontal supporting forces shall be increased by the values calculated using the following formulae:

$$P'_{ri} = P_{ri} + \Delta P_r, \quad [\text{kN}] \quad (3.8.4.3-1)$$

$$P'_{rj} = P_{rj} + \Delta P_r, \quad [\text{kN}] \quad (3.8.4.3-2)$$

$$P'_{rk} = P_{rk} + \Delta P_r, \quad [\text{kN}] \quad (3.8.4.3-3)$$

$$P'_{rm} = P_{rm} + \Delta P_r, \quad [\text{kN}] \quad (3.8.4.3-4)$$

$$\Delta P_r = [P_{sh} - 0.5f(M_a)g_o] \left( \frac{1}{m} + \frac{1}{k} + \frac{1}{j} + \frac{1}{i} \right) \frac{b_s}{h}, \quad [\text{kN}] \quad (3.8.4.3-5)$$

$f(M_a)$  – according to 3.8.2.1

**3.8.4.4** The maximum vertical supporting force is determined by:

$$P_s = f(M_a)g_o + \sum P_{sl}, \quad [\text{kN}] \quad (3.8.4.4)$$

$\sum P_{sl}$  – sum of vertical components of lashing forces, [kN].

**ANNEX 1**

**FORMULAE FOR CALCULATION OF HORIZONTAL AND VERTICAL SUPPORTING FORCES  
FOR TYPICAL CASES OF CONTAINER STACK LASHING**

Item	Lashing pattern	Horizontal supporting force $P_r$ , [kN]	Vertical supporting force $P_{sh}$ , [kN]
1	Single rigid support	$P_{ri} = \frac{K_c(\delta_{io} - \delta_{ic})}{i}, \delta_{ic} < \delta_{io}$	$P_{sh} = \frac{[f(P_{ha}) - iP_{ri}]h}{b_s}$ $f(P_{ha}) = 0.5P_h n^2 \text{ or}$ $f(P_{ha}) = \sum_{a=1}^n (a - 0.5)P_{ha}$
2	Double rigid support (two supports)	$P_{ri} = \frac{K_c[i(\delta_{jo} - \delta_{jc}) - j(\delta_{jo} - \delta_{ic})]}{i^2 - ij}$ $P_{rj} = \frac{K_c[(\delta_{jo} - \delta_{jc}) - (\delta_{io} - \delta_{ic})]}{j - i}$	$P_{sh} = \frac{[f(P_{ha}) - (iP_{ri} + jP_{rj})]h}{b_s}$
3	Triple rigid support (three supports)	$P_{ri} = \frac{K_c[i(\delta_{jo} - \delta_{jc}) - j(\delta_{io} - \delta_{ic})]}{i^2 - ji}$ $P_{rj} = K_c \left[ \frac{(\delta_{jo} - \delta_{jc}) - (\delta_{io} - \delta_{ic})}{j - i} - \frac{(\delta_{ko} - \delta_{kc}) - (\delta_{jo} - \delta_{jc})}{k - j} \right]$ $P_{rk} = \frac{K_c[(\delta_{ko} - \delta_{kc}) - (\delta_{jo} - \delta_{jc})]}{k - j}$	$P_{sh} = \frac{[f(P_{ha}) - (iP_{ri} + jP_{rj} + kP_{rk})]h}{b_s}$
4	Single flexible support	$P_{ri} = \frac{K_c \delta_{io}}{\frac{K_c}{K_i} + i}$	See item 1

Item	Lashing pattern	Horizontal supporting force $P_r$ , [kN]	Vertical supporting force $P_{sh}$ , [kN]
5	Flexible lower support and rigid top support	$P_{ri} = \frac{K_c [i(\delta_{jo} - \delta_{jc}) - j\delta_{io}]}{i^2 - \left(\frac{K_c}{K_i} + i\right)j}$ $P_{rj} = \frac{K_c \left[ \left(\frac{K_c}{K_i} + i\right)(\delta_{jo} - \delta_{jc}) - i\delta_{io} \right]}{\left(\frac{K_c}{K_i} + i\right)j - i^2}$	See item 2
6	Two flexible supports	$P_{ri} = \frac{\left[ K_c i \delta_{jo} - \left(\frac{K_c}{K_j} + j\right) \delta_{io} \right]}{i^2 - \left(\frac{K_c}{K_i} + i\right) \left(\frac{K_c}{K_j} + j\right)}$ $P_{rj} = \frac{K_c \left[ \left(\frac{K_c}{K_i} + i\right) \delta_{jo} - i \delta_{io} \right]}{\left(\frac{K_c}{K_i} + i\right) \left(\frac{K_c}{K_j} + j\right) - i^2}$	See item 2
7	Rigid top support and two flexible supports	$P_{ri} = K_c \frac{(\delta_{ko} - \delta_{kc})(j - c_j)i + \delta_{io}(kc_j - j^2) + i\delta_{jo}(j - k)}{(kc_j - j^2)c_i + (2j - k - c_j)i^2}$ $P_{rj} = K_c \frac{(\delta_{ko} - \delta_{kc})(i^2 - jc_j) + ic_{io}(j - k) + \delta_{jo}(kc_i - i^2)}{(kc_j - j^2)c_i + (2j - k - c_j)i^2}$ $P_{rk} = K_c \frac{(\delta_{ko} - \delta_{kc})(c_i c_j - i^2) + i\delta_{io}(j - c_j) + \delta_{jo}(i^2 - jc_i)}{(kc_j - j^2)c_i + (2j - k - c_j)i^2}$	See item 3

Item	Lashing pattern	Horizontal supporting force $P_r$ , [kN]	Vertical supporting force $P_{sh}$ , [kN]
		$c_i = \frac{K_c}{K_i} + i, \quad c_j = \frac{K_c}{K_j} + j$	
8	Three flexible supports	$P_{ri} = K_c \frac{i\delta_{ko}(j - c_j) + i\delta_{jo}(j - c_k) + \delta_{io}(c_j c_k - j^2)}{c_i c_j c_k - j^2 c_i + i^2 (2j - c_j - c_k)}$ $P_{rj} = K_c \frac{\delta_{ko}(i^2 + j c_i) + \delta_{jo}(c_i c_k - i^2) + i\delta_{io}(j + c_k)}{c_i c_j c_k - j^2 i + i^2 (2j - c_j - c_k)}$ $P_{rk} = K_c \frac{\delta_{ko}(c_i c_j - i^2) + c_{jo}(i^2 - j c_i) + i\delta_{io}(j - c_j)}{c_i c_j c_k - j^2 c_i + i^2 (2j - c_j - c_k)}$ $c_i = \frac{K_c}{K_i} + i, \quad c_j = \frac{K_c}{K_j} + j, \quad c_k = \frac{K_c}{K_k} + k$	See item 3



ANNEX 2

EXEMPLARY CALCULATIONS FOR TYPICAL STACKS OF CONTAINERS

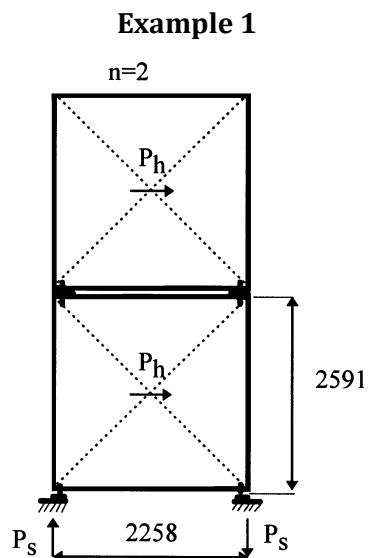


Fig. 1

A two-tier stack of containers shown in Fig. 1 is secured with twistlocks. Twistlocks are also applied between the tiers.

Data:

Container mass	$M_1 = M_2 = 24 \text{ t};$
Resultant transverse acceleration	$a_t = 6.5 \text{ m/s}^2;$
Resultant vertical acceleration	$a_v = 7.5 \text{ m/s}^2;$
Resultant longitudinal acceleration	$a_l = 2.8 \text{ m/s}^2;$
Roll angle	$\varphi = 27^\circ;$
Wind force	$P_w = 18.5 \text{ kN}.$

It was assumed that the values of accelerations  $a_v$  and  $a_l$  acting on the individual containers in a stack are the same.

The horizontal transverse force acting on a container frame is:

$$P_h = 0.5(Ma_t + P_w) = 0.5(24 \cdot 6.5 + 18.5) = 87.25 \text{ kN}$$

The transverse racking force  $S_r$  acting on the container in the lowest tier is:

$$S_r = (n - 1 + \alpha)P_h = (2 - 1 + 0.5) \cdot 87.25 = 130.88 \text{ kN}$$

The vertical reactive force  $P_{sh}$  in the deck sockets is:

$$P_{sh} = \frac{h}{2258} \cdot 0.5 \cdot P_h \cdot n^2 = 1.15 \cdot 0.5 \cdot 87.25 \cdot 4 = 200.68 \text{ kN}$$

The compressive force  $P_{ch}$  acting on the lowest tier corner post is:

$$P_{ch} = P_{sh} - \frac{P_{h1} \cdot h_l}{2b} = 200.68 - \frac{87.25 \cdot 2591}{2 \cdot 2258} = 150.62 \text{ kN}$$

The maximum horizontal reactive forces  $P_{sc}$  and  $P_{st}$  acting on the socket are:

$$P_{sc} = 0.25 \cdot n \cdot M \cdot g_o + P_{sh} = 0.25 \cdot 2 \cdot 24 \cdot 9.81 + 200.68 = 318.4 \text{ kN}$$

$$P_{sc} = 0.25 \cdot n \cdot M (g_o + a_v) = 0.25 \cdot 2 \cdot 24 \cdot (9.81 + 7.5) = 207.72 \text{ kN}$$

$$P_{st} = 0.25 \cdot n \cdot M \cdot g_o \cdot \cos \varphi - P_{sh} = -95.8 \text{ kN}$$

The maximum vertical force  $P_c$  compressing the corner post is:

$$P_c = 0.25(n-1)M(g_o + a_v) = 0.25(2-1)24(9.81 + 7.5) = 103.8 \text{ kN}$$

$$P_c = 0.25(n-1)Mg_o + P_{ch} = 0.25(2-1)24 \cdot 9.81 + 150.62 = 209.5 \text{ kN}$$

Calculation of the longitudinal horizontal force  $S_r$  acting on the top side rail of a container in the lowest tier is:

$$P_h = 0.5(Ma_l + P_w) = 0.5(24 \cdot 2.8 + 8) = 37.6 \text{ kN},$$

$$S_r = (n-1 + \alpha)P_h = (2-1 + 0.5)37.6 = 56.4 \text{ kN}$$

The following results have been obtained:

Force	Value [kN]	Permissible value [kN]
$S_{r \text{ transv.}}$	130.88	150
$S_{r \text{ longit.}}$	56.40	75
$P_{sc}$	318.40	715
$P_{st}$	- 95.80	
$P_c$	209.50	635

The above calculations prove that none of the calculated forces exceeds the permissible value.

The calculations of  $P_{st}$  prove that the corner shall be subject to pulling off the base. Therefore a twistlock of  $SWL_{\min} = 95.8 \text{ kN}$  shall be used.

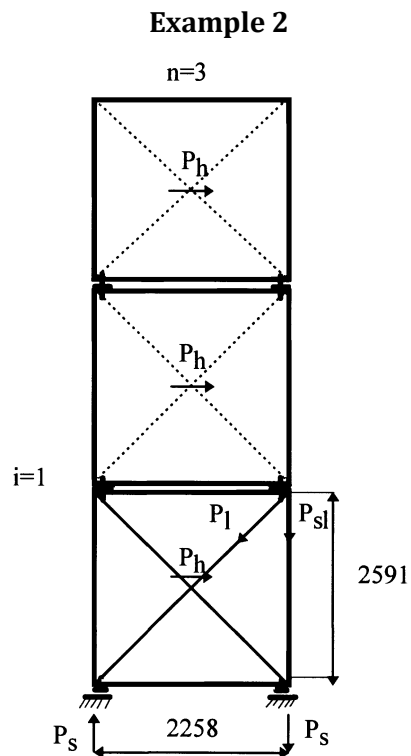


Fig. 2

A three tier stack of containers shown in Fig. 2 is secured to the lower corner fittings of the second container in a stack by means of single cross lashings.

Data:

container mass  $M_1 = M_2 = M_3 = 30 t$ ,

resultant transverse acceleration  $a_t = 6.67 \text{ m/s}^2$ ;

resultant vertical acceleration  $a_v = 7.6 \text{ m/s}^2$ ;

roll angle  $\varphi = 27^\circ$ ;

lashing wire  $\varnothing = 22 \text{ mm}$ ;  $E_l = 75 \text{ kN/mm}^2$ ;

wind force  $P_w = 0$ ;

permissible force in lashing wire  $Z = 153 \text{ kN}$ .

The horizontal transverse force acting on a half of a container:

$$P_{ht} = 0.5(M \cdot a_t + P_w) = 0.5 \cdot 30 \cdot 6.67 = 100 \text{ kN}$$

The horizontal spring stiffness of a lashing wire is:

$$K_i = \frac{E_l A_l S_l^2}{\sqrt{(h_l^2 + S_l^2)^3}} = \frac{75\pi \frac{22^2}{4} 2258^2}{\sqrt{(2591^2 + 2258^2)^3}} = 3.58 \text{ kN/mm}$$

**Calculations for a doorless end**

Data:

$$K_c = 10 \text{ kN/mm}$$

Free displacement on level  $i$  is:

$$\delta_{io} = \frac{P_{hi}}{K_c} \left( \sum_{a=1}^i (n-a) + i\alpha \right) = \frac{100}{10} 2.5 = 25 \text{ mm}$$

The horizontal reactive force of lashing wire is:

$$P_{ri} = \frac{K_c \cdot \delta_{io}}{\left( \frac{K_c}{K_i} + i \right)} = \frac{10 \cdot 25}{\left( \frac{10}{3.58} + 1 \right)} = 66 \text{ kN } (< 150 \text{ kN})$$

The vertical component of the reactive force in the stowage bottom socket is:

$$P_{sh} = \frac{[f(P_{ha}) - iP_{ri}]h}{b_s} = \frac{(0.5 \cdot 100 \cdot 3^2 - 66) \cdot 2591}{2258} = 441 \text{ kN}$$

The longitudinal force in a lashing wire at level  $i$  after simplification of the formulae is:

$$P_{li} = 66 \frac{\sqrt{2591^2 + 2258^2}}{2258} = 100.5 \text{ kN } (< 153 \text{ kN})$$

The vertical component of the lashing force is:

$$P_{sl} = P_{ri} \frac{h}{S_l} = 66 \frac{2591}{2258} = 76 \text{ kN}$$

The maximum vertical reactive forces in the stowage bottom sockets are:

– in the right bottom socket (on the compression side):

$$P_{sc} = 0.25nM(g_o + a_v) = 0.25 \cdot 3 \cdot 30(9.81 + 7.6) = 391.7 \text{ kN},$$

$$P_{sc} = 0.25nMg_o + P_{sh} + \sum P_{sl} = 0.25 \cdot 3 \cdot 30 \cdot 9.81 + 441 + 76 = 737.5 \text{ kN } (< 950 \text{ kN})$$

– in the left bottom socket (on the tension side):

$$P_{st} = 0.25nMg_o \cos \varphi - P_{sh} = 0.25 \cdot 3 \cdot 30 \cdot 9.81 \cdot \cos 27^\circ - 441 = -244 \text{ kN}$$

The calculation of  $P_{st}$  proves that the corner fitting will be subject to pulling off the base, therefore a twistlock or any similar device of  $MSL_{\min} = 244 \text{ kN}$ , which prevents pulling off the base, shall be used.

The maximum vertical compressive force acting on the lowest tier corner post is:

$$P_c = 0.25(n-1)Mg_o + P_{ch} + \sum P_{sl} = 0.25(3-1) \cdot 30 \cdot 9.81 + 441 - \frac{100 \cdot 2591}{2 \cdot 2258} = 531 \text{ kN } (< 845 \text{ kN})$$

The transverse racking force in the header of the lowest tier container is:

$$S_r = (n-1+\alpha)P_h - \sum P_r = (3-1+0.5) \cdot 100 - 66 = 184 \text{ kN } (> 150 \text{ kN})$$

As the racking force exceeds the permissible value for both door and doorless ends, either lashings of greater stiffness shall be used or the containers shall be lighter.

The lashing wire of  $\varnothing 30 \text{ mm}$ ,  $E_l = 75 \text{ kN/mm}$  and  $Z = 187 \text{ kN}$  is used.

### Verifying calculations

$$K_i = \frac{75 \cdot \pi \cdot \frac{30^2}{4} \cdot 2258^2}{\sqrt{(2591^2 + 2258^2)^3}} = 6.66 \text{ kN/mm};$$

$$P_{ri} = \frac{10 \cdot 25}{\left(\frac{10}{6.66} + 1\right)} = 100 \text{ kN (< 150 kN)}$$

$$P_{sh} = \frac{(0.5 \cdot 100 \cdot 3^2 - 100) \cdot 2591}{2258} = 402 \text{ kN}$$

$$P_{li} = 100 \frac{\sqrt{2591^2 + 2258^2}}{2258} = 152.21 \text{ kN}$$

$$P_{sl} = 100 \frac{2591}{2258} = 114.75 \text{ kN}$$

$$P_{sc} = 0.25 \cdot 3 \cdot 30 \cdot 9.81 + 402 + 114.75 = 737.5 \text{ kN (< 950 kN)}$$

$$P_{st} = 0.25 \cdot 3 \cdot 30 \cdot 9.81 \cdot \cos 27^\circ - 402 = -205.33 \text{ kN}$$

$$P_c = 0.25 \cdot 2 \cdot 30 \cdot 9.81 + 402 - \frac{100 \cdot 2591}{2 \cdot 2258} = 491.74 \text{ kN (< 845 kN)}$$

$$S_r = (3 - 1 + 0.5) \cdot 100 - 100 = 150 \text{ kN}$$

With the change of a lashing wire to another of  $\varnothing 30$  mm, the existing forces in both lashing system and the door/doorless frame of the container do not exceed the allowable values. Such a lashing wire is permitted provided the twistlock or other securing device of  $SWL_{\min} = 206$  kN is used.

### Calculations for door ends

Data:

$$K_c = 3.85 \text{ kN/mm};$$

$$\delta_{io} = \frac{100}{3.85} \cdot 2.5 = 65 \text{ mm};$$

$$P_{ri} = \frac{3.85 \cdot 65}{\left(\frac{3.85}{6.66} + 1\right)} = 158.6 \text{ kN (> 150 kN)};$$

$$P_{sh} = \frac{(0.5 \cdot 100 \cdot 3^2 - 158.6) \cdot 2591}{2258} = 334.4 \text{ kN}$$

$$P_{li} = 158.6 \frac{\sqrt{2591^2 + 2258^2}}{2258} = 241.4 \text{ kN (> 187 kN)}$$

$$P_{sl} = 158.6 \frac{2591}{2258} = 182.0 \text{ kN};$$

$$P_{sc} = 0.25 \cdot 3 \cdot 30 \cdot 9.81 + 334.4 + 182.0 = 737.13 \text{ kN (< 950 kN)}$$

$$P_{st} = 0.25 \cdot 3 \cdot 30 \cdot 9.81 \cdot \cos 27^\circ - 334.4 = -138 \text{ kN};$$

$$S_r = (3 - 1 + 0.5) \cdot 100 - 158.6 = 91.4 \text{ kN} (< 150 \text{ kN})$$

As the magnitudes of forces  $P_{ri}$  and  $P_{li}$  exceed the allowable values, the proposed lashing pattern is unacceptable. Either the containers shall be lighter or different type lashings shall be used and the calculations shall be repeated.

### Example 3

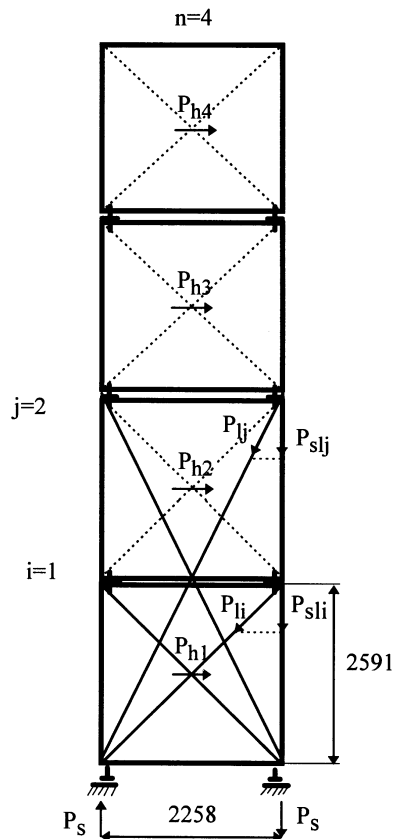


fig. 3

A four-tier stack of containers shown in Fig. 3 is secured by two cross lashings attached to the lower corner fittings of the second tier of containers and to the lower fittings of the third tier.

Data:

container mass – see the table below;

resultant transverse acceleration (calculated for each tier) – see the table below;

resultant vertical acceleration  $a_v = 4.2 \text{ m/s}^2$ ;

roll angle  $\varphi = 25^\circ$ ;

lashing rods of  $\varnothing 25 \text{ mm}$ ;  $l_i = 3436 \text{ mm}$ ,  $l_j = 5650 \text{ mm}$ ;

$E_{li} = 97.44 \text{ kN/mm}^2$  and  $E_{lj} = 186 \text{ kN/mm}^2$

$Z = 188 \text{ kN}$

Tier	Container mass $M$ [t]	Resultant transverse acceleration $a_t$ [m/s <sup>2</sup> ]	Horizontal transverse force $P_{ht}$ [kN]
1	30	6.10	91.5
2	30	6.25	93.7
3	30	6.40	96.0
4	3	6.55	9.8

The horizontal spring stiffness of lashings is:

$$K_i = \frac{E_{li} A_{li} S_{li}^2}{\sqrt{(h_{li}^2 + S_{li}^2)^3}} = \frac{97.44 \cdot \pi \cdot 12.5^2 \cdot 2258^2}{\sqrt{(2591^2 + 2258^2)^3}} = 6.01 \text{ kN/mm}$$

$$K_j = \frac{186 \cdot \pi \cdot 12.5^2 \cdot 2258^2}{\sqrt{(4 \cdot 2591^2 + 2258^2)^3}} = 2.58 \text{ kN/mm}$$

### Calculations for the door/doorless end

Data:

$$K_c = 10 \text{ kN/mm}$$

Free displacements at levels  $i$  and  $j$  are:

$$\delta_{io} = \frac{1}{10} (0.25 \cdot 91.5 + 93.7 + 96.0 + 9.8) = 22.2 \text{ mm};$$

$$\delta_{jo} = \frac{1}{10} [0.25(91.5 + 93.7) + 96.0 + 9.8 + 93.7 + 96.0 + 9.8] = 35.2 \text{ mm}$$

The horizontal reactive forces in the lashings are:

$$P_{ri} = \frac{10 \left[ 35.2 - \left( \frac{10}{2.58} + 2 \right) \right] 22.2}{1 - \left( \frac{10}{6.01} + 1 \right) \left( \frac{10}{2.58} + 2 \right)} = 65 \text{ kN} (< 150 \text{ kN})$$

$$P_{rj} = \frac{10 \left[ \left( \frac{10}{6.01} + 1 \right) 35.2 - 22.2 \right]}{\left( \frac{10}{6.01} + 1 \right) \left( \frac{10}{2.58} + 2 \right) - 1} = 48.8 \text{ kN} (< 150 \text{ kN})$$

The horizontal component of the reactive force in the deck socket is:

$$P_{sh} = \frac{(0.5 \cdot 91.5 + 1.5 \cdot 93.7 + 2.5 \cdot 96 + 3.5 \cdot 9.8 - 65 - 2 \cdot 48.8) 2591}{2258} = 341.8 \text{ kN}$$

Longitudinal lashing forces at levels  $i$  and  $j$  are:

$$P_{li} = 65 \frac{\sqrt{2591^2 + 2258^2}}{2258} = 98.8 \text{ kN} (< 188 \text{ kN})$$

$$P_{ij} = 48.8 \frac{\sqrt{4 \cdot 2591^2 + 2258^2}}{2258} = 122.1 \text{ kN (< 188 kN)}$$

Vertical components of the lashing forces are:

$$P_{sli} = 65 \frac{2591}{2258} = 74.5 \text{ kN}$$

$$P_{slj} = 48.8 \frac{2 \cdot 2591}{2258} = 111.9 \text{ kN}$$

Maximum vertical reactive forces in the stowage bottom sockets are:

– the right socket (on compression side)

$$P_{sc} = 0.25(3 \cdot 30 + 3)(9.81 + 4.2) = 325.7 \text{ kN (< 950 kN)};$$

$$P_{sc} = 0.25 \cdot 93.0 \cdot 9.81 + 341.8 + 74.5 + 111.9 = 756 \text{ kN (< 950 kN)};$$

– the left socket (on tension side)

$$P_{sc} = 325.7 \text{ kN}$$

$$P_{st} = 0.25 \cdot 93 \cdot 9.81 \cdot \cos 25^\circ - 341.8 = -135.1 \text{ kN}$$

The maximum vertical compressive force acting on the lowest tier corner post is:

$$P_c = 0.25(2 \cdot 30 + 3)9.81 + 341.8 - \frac{91.5 \cdot 2591}{2 \cdot 2258} + 74.5 + 111.9 = 630.2 \text{ kN (< 845 kN)}$$

The transverse racking force acting on the header of the container in the lowest tier is:

$$S_r = 0.5 \cdot 91.5 + 93.7 + 96.0 + 9.8 - 65 - 48.8 = 131.45 \text{ kN (< 150 kN)}$$

### **Calculations for the case of tipping of the three upper tiers of containers**

The vertical component of the reactive force in the lower corner fitting of the second container in a stack is:

$$P_{sh} = \frac{2591}{2258}(0.5 \cdot 93.7 + 1.5 \cdot 96 + 2.5 \cdot 9.8 - 48.8) = 191 \text{ kN}$$

The maximum vertical reactive force in the lower left corner fitting of the second tier of containers is:

$$P_{st} = 0.25 \cdot 63 \cdot 9.81 \cdot \cos 25^\circ - 191 = -51 \text{ kN}$$

The transverse racking force acting on the header of the second tier of containers is:

$$S_r = 0.5 \cdot 93.7 + 96 + 9.8 - 48.8 = 103.85 \text{ kN (< 150 kN)}.$$



### Calculations for the door end

Data:

$$K_c = 3.85 \text{ kN/mm};$$

$$\delta_{io} = 22.2 \cdot \frac{10}{3.85} = 57.7 \text{ mm};$$

$$\delta_{jo} = 35.2 \cdot \frac{10}{3.85} = 91.4 \text{ mm};$$

$$P_{ri} = \frac{3.85 \left[ 91.4 - \left( \frac{3.85}{2.58} + 2 \right) 57.7 \right]}{1 - \left( \frac{3.85}{6.01} + 1 \right) \left( \frac{3.85}{2.58} + 2 \right)} = 89.6 \text{ kN} (< 150 \text{ kN});$$

$$P_{rj} = \frac{3.85 \left[ \left( \frac{3.85}{6.01} + 1 \right) 91.4 - 57.7 \right]}{\left( \frac{3.85}{6.01} + 1 \right) \left( \frac{3.85}{2.58} + 2 \right) - 1} = 75.1 \text{ kN} (< 150 \text{ kN});$$

$$P_{sh} = \frac{2591}{2258} (0.5 \cdot 91.5 + 1.5 \cdot 93.7 + 2.5 \cdot 96 + 3.5 \cdot 9.8 - 89.6 - 2 \cdot 75.1) = 253.3 \text{ kN}$$

$$P_{li} = 98.8 \cdot \frac{89.6}{65} = 136.2 \text{ kN} (< 188 \text{ kN});$$

$$P_{lj} = 122.1 \cdot \frac{75.1}{48.8} = 187.9 \text{ kN} (< 188 \text{ kN});$$

$$P_{sli} = 89.6 \cdot \frac{2591}{2258} = 102.8 \text{ kN};$$

$$P_{slj} = 75.1 \cdot \frac{2 \cdot 2591}{2258} = 172.3 \text{ kN};$$

$$P_{sc} = 325.7 \text{ kN};$$

$$P_{sc} = 0.25 \cdot 93 \cdot 9.81 + 253.3 + 102.8 + 172.3 = 756.5 \text{ kN} (< 950 \text{ kN})$$

- for the right bottom stowage socket;

$$P_{sc} = 325.7 \text{ kN}$$

$$P_{st} = 0.25 \cdot 93 \cdot 9.81 \cdot \cos 25^\circ - 253.3 = -46.6 \text{ kN} \quad \text{- for the left bottom stowage socket;}$$

$$P_c = 0.25(2 \cdot 30 + 3) \cdot 9.81 + 253.3 - \frac{91.5 \cdot 2591}{2 \cdot 2258} + 102.8 + 172.8 = 630 \text{ kN} (< 845 \text{ kN}) \quad \text{- for the lowest container;}$$

$$S_r = 0.5 \cdot 91.5 + 93.7 + 96 + 9.8 - 89.6 - 75.1 = 80.55 \text{ kN} (< 150 \text{ kN}) \quad \text{- for the lowest container.}$$

### Conclusion:

The forces in the door/doorless ends, as well as in the lashing system do not exceed the permissible values. The lashings used to secure the containers and the lashings are appropriate.

**Note:**

The racking forces acting on the side wall frames determined in examples 1, 2 and 3 shall be calculated in accordance with 3.5.2.7 of this *Publication*.

The horizontal longitudinal forces shall be calculated in accordance with 3.5.2.4 assuming that the containers are not secured in the longitudinal direction ( $\sum P_r = 0$ ).

**4 STOWAGE AND LASHING OF ROAD VEHICLES AND ROLL-TRAILERS****4.1 General Requirements and Application**

**4.1.1** The requirements of this Chapter apply to ro-ro and con-ro ships, as well as to ferries which carry road vehicles and roll-trailers on open seas and also to:

- .1** road vehicles specified in 4.2.1, 4.2.2, 4.2.3, 4.2.5, whose running weight (i.e. combined weight of a vehicle and cargo) ranges from 3.5 t to 40 t,
- .2** articulated road trains specified in 4.2.4, whose running weight (i.e. combined weight of a vehicle and cargo) does not exceed 45 t which may be carried by the ro-ro, con-ro ships and ferries,
- .3** roll-trailers specified in 4.2.6, whose running weight (i.e. combined weight of a trailer and cargo) may not exceed the permissible deck load values.

**4.1.2** The requirements of this Chapter apply to the ships that are assigned an additional mark, such as **RO-RO SHIP**, **FERRY**, **FERRY/PASSENGER SHIP** and **SD** or **MD** in their symbol of class.

**4.1.3** The requirements of this Chapter do not apply to buses.

**4.1.4** Road vehicles and roll-trailers shall be so stowed and lashed on a ship as provided in the documentation developed in accordance with this Chapter and approved by PRS. Preparation of road vehicles to be carried by sea applies only to those vehicles which are intended to be carried by a means of sea transport.

**4.1.5** The stowage and lashing of road vehicles and roll-trailers on board the ship which is different from that described in 4.1.4 shall be preceded by the calculations made as provided in this Chapter and subsequently approved by PRS.

**4.1.6** The containers stowed on decks which are intended for the carriage of road vehicles and roll-trailers as well as the containers loaded on roll-trailers shall fulfil the requirements specified in Chapter 3 of this *Publication*.

**4.1.7** Fixed and portable securing devices for lashing of road vehicles and roll-trailers shall fulfil the requirements specified in Chapter 2 of this *Publication*. This Chapter does not comprise such portable securing devices as: wheel chocks, air bags, rubber pads, etc.

**4.2 Definitions**

**4.2.1** Commercial vehicle – a motor vehicle which, on account of its design and appointments, is used mainly for conveying goods. It may be towing a trailer.

**4.2.2** Semi-trailer – a trailer which is designed to be coupled to a semi-trailer towing vehicle and to impose a substantial part of its total mass on the towing vehicle.

**4.2.3** Road train – combination of a motor vehicle with one or more independent trailers connected by draw-bar.

**4.2.4** Articulated road train – combination of a vehicle towing vehicle with a semi-trailer or semi-trailers.

**4.2.5** Combination of vehicles – a motor vehicle coupled with one or more towed vehicles (for the purpose of sub-chapter 4.3, each element of a combination of vehicles is considered a separate vehicle).

**4.2.6** Roll-trailer – a low vehicle for the carriage of cargo with one or more wheel axles on the rear and a support on the front end, which is towed or pushed in the port to and from its stowage on board the ship by a special tow-vehicle.

### **4.3 Technical Requirements**

#### **4.3.1 Arrangement of Deck Sockets and Securing Points on Ships' Decks**

**4.3.1.1** The decks of ships intended for the carriage of road vehicles and roll-trailers shall be provided with the purpose-designed deck sockets (flush deck sockets, cross sockets, lashing plates, lashing rings etc.). The arrangement of securing points, their number and strength shall fulfil the following requirements:

- .1** the distance between securing points in the longitudinal direction shall not exceed 2.5 m (the distance between the securing points equal to double frame spacing is recommended). However, there may be a need for the securing points in the forward and after parts of the ship to be more closely spaced than they are amidships;
- .2** the athwartship spacing of securing points shall not be less than 2.8 m and not more than 3 m. Due to the less width of a ship, there may be a need for the securing points in the forward and after parts of the ship to be more closely spaced than they are amidships to allow proper lashing of vehicles and roll-trailers;
- .3** the maximum securing load (*MSL*) of each securing point shall not be less than 100 kN. If the securing point is designed to accommodate more than one lashing (*y* lashings), the *MSL* shall not be less than  $y \times 100$  kN.

**4.3.1.2** Ships intended mainly for the carriage of roll-trailers carrying container stacks or heavy machinery shall be provided with securing points spaced appropriately and strong enough to secure the roll-trailers or other ro-ro cargo units by means of lashing them to the ship decks.

**4.3.1.3** In ro-ro ships which only occasionally carry road vehicles, the spacing and strength of securing points should be such that the special considerations which may be necessary to stow and secure road vehicles safely are taken into account.

#### **4.3.2 Arrangement of Securing Points on Road Vehicles and Roll-trailers**

**4.3.2.1** All road vehicles and/or roll-trailers may be provided with the following kinds of securing points:

- .1** cargo securing points – intended for lashing of cargo to a road vehicle or roll-trailer; they shall be so designed and spaced and have such dimensions that the maximum mass of the cargo is safely secured during transport by sea;
- .2** transport securing points – intended for lashing a road vehicle or roll-trailer to the ship deck; they shall fulfil the requirements specified in 4.3.2.4 and 4.3.2.5;
- .3** securing points are acceptable to be so made that they play the role of both cargo securing points and transport securing points, provided that strength calculations justify this.

**4.3.2.2** In addition to the securing arrangements specified in 4.3.2.1, roll-trailers may be provided with fixed twistlocks or sockets whose longitudinal and athwartship arrangement as well as dimensions shall fulfil ISO requirements. The fixed twistlocks shall have the strength meeting the requirements specified in Chapter 2 of this Publication.

**4.3.2.3** The same number of not fewer than two and not more than six transport securing points shall be provided on each side of the road vehicle. One securing point shall be provided on each side of the roll-trailer where a trailer frame support is intended to be applied – these securing points count among the required number of the transport securing points.

**4.3.2.4** The same number of not fewer than six transport securing points, hereinafter referred to as securing points, shall be provided on each side of a roll-trailer. This number does not include the securing points situated on the front beams of roll-trailers. The securing points on the front beams shall be identical with those on the side beams and their number shall not be less than two on each front beam.

**4.3.2.5** The minimum number of securing points ( $n$ ) on each side of a vehicle and their maximum securing load ( $MSL$ ) depending on the gross vehicle mass ( $GVM$ ) are given in Table 4.3.2.5. The maximum securing load ( $MSL$ ) of lashings shall not be less than 100 kN and they shall be made of material having suitable elongation characteristics.

However, for vehicles not exceeding 15 tonnes ( $GVM$ ), lashing with lower  $MSL$  values may be used. The required number and  $MSL$  of lashings may be calculated according to annex 13 to the Code of Safe Practice for Cargo Stowage and Securing (CSS Code), taking into consideration the following criteria:

- dimensional and physical properties of the cargo;
- location of the cargo and its stowage on board;
- suitability of the ship for the particular cargo;
- suitability of the securing arrangement for the particular cargo;
- expected seasonal weather and sea conditions;
- expected ship behaviour during the intended voyage;
- stability of the ship;
- geographical area of the voyage; and
- duration of the voyage.

**Table 4.3.2.5**

Gross vehicle mass ( $GVM$ ) [t]	Minimum number of securing points on each side of a vehicle ( $n$ )	Maximum securing load ( $MSL$ ) of each securing point (without permanent deformation) [kN]
$3.5 \leq GVM \leq 20$	2	$MSL = \frac{GVM \cdot 12}{n}$
$20 < GVM \leq 30$	3	
$30 < GVM \leq 40$	4	

**4.3.2.6** For road trains, Table 4.3.2.5 applies to each component, i.e. to the motor vehicle and each trailer, respectively.

**4.3.2.7** Semi-trailer towing vehicles are excluded from Table 4.3.2.5. They shall be provided with two securing points at the front of the vehicle, strength of which shall be sufficient to prevent lateral movement of the front of the vehicle. A towing coupling at the front may replace the two securing points.

**4.3.2.8** If the towing coupling is used for securing vehicles other than semi-trailer towing vehicles, this is not to replace or be substituted for the minimum number and strength of securing points on each side of the vehicle specified in Table 4.3.2.5.

**4.3.2.9** For road vehicles and roll-trailers having characteristics outside the general parameters for road vehicles and roll-trailers (particularly where the normal height of the centre of gravity is exceeded), the location and the number of securing points is subject to consideration: by PRS – for roll-trailers, and by a competent authority – for road vehicles.

**4.3.2.10** Each securing point on vehicles and roll-trailers shall be marked in a clearly visible colour.

**4.3.2.11** Securing points shall be so located as to ensure effective restraint of the road vehicle or roll-trailer by the lashings.

**4.3.2.12** Securing points shall be capable of transferring the forces, occurring during the sea transport, from the lashings to the chassis of the road vehicle and shall never be fitted to bumpers or axles unless these are specially constructed and the forces are transmitted directly to the chassis.

**4.3.2.13** Securing points shall be so located that lashings can be readily and safely attached, particularly where side-guards are fitted to the vehicle (safety rail, balustrades, etc.).

**4.3.2.14** The internal free passage of each securing point's aperture shall not be less than 80 mm and the aperture does not need to be circular in shape but the minimum internal free passage shall not be less than 80 mm.

**4.3.2.15** Equivalent securing arrangements may be applied on vehicles whose number and maximum securing load (MSL) are different from those specified in Table 4.3.2.5 after an approval of the vehicle certifying authority has been obtained.

**4.3.2.16** Securing points on road vehicles should be designed for securing the road vehicles to the ship and should have an aperture capable of accepting only one lashing. The securing point and aperture should permit varying directions of the lashing to the ship's deck.<sup>1</sup>

### **4.3.3 Stowage and Lashing of Road Vehicles and Roll-trailers on Ship Decks**

**4.3.3.1** Lashings shall be so attached to the securing points on the vehicle or roll-trailer that angle  $\gamma$  (see Fig. 4.4.2.6) does not exceed 60°.

**4.3.3.2** Where the expected weather conditions on the intended voyage are worse than assumed in the strength calculations for lashings, the number of lashings securing the vehicles and roll-trailers shall be increased respectively, previously calculating their strength in accordance with Chapter 4.4, and/or the vehicles and roll-trailers shall be side-chocked with air bags.

**4.3.3.3** Where heavy weather conditions – with marked slamming shocks in particular – may be expected for the intended voyage, additional securing of the trestles against slipping from under the semi-trailers is required. This may be achieved by additional fastening of the trestles to the chassis with fibre ropes or other equivalent means.

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<sup>1</sup> If more than one aperture is provided at a securing point, each aperture should have the strength for the securing point in the Table 4.3.2.5.

**4.3.3.4** Lashing of vehicles with their suspension system (springs, pneumatic and/or hydraulic systems, wheels) unrestrained is not allowed. Elimination of free play in the suspension may be done by:

- compressing the springs by tightly securing the vehicle to the deck with lashings;
- jacking up the chassis with appropriate supports in jacking-up points (using appropriate hoists prior to securing the vehicle);
- releasing the air pressure in compressed air suspension systems.

Exceptionally, the decision concerning carriage of vehicles with free play in their suspension may be taken by the crew member responsible for the stowage and lashing of vehicles after comprehensive consideration of the weather and sea conditions expected on the intended voyage and all other circumstances. Special care shall be taken while securing with lashings near the springy supports (i.e. vehicle wheels).

**4.3.3.5** Taking into account the conditions referred to in 4.3.3.6 and the fact that compressed air suspension systems may lose air, the air pressure shall be released on every vehicle fitted with such a system if the voyage is of more than 24 hours duration.

If practicable, the air pressure shall be released also on voyages of a shorter duration.

If the air pressure is not released, the vehicle shall be jacked up and properly supported.

During the voyage the lashings shall be regularly inspected, if the weather and sea conditions allow safe working by the persons inspecting the tightness and retightening the lashings.

**4.3.3.6** Where jacks, supports and trestles are used on a vehicle, the chassis shall be strengthened in way of the jacking-up points and the position of these points shall be clearly marked.

**4.3.3.7** Vehicles and roll-trailers shall be positioned parallel with the ship's plane of symmetry. Door ends of containers stowed on internal ramps or in other sloping deck areas shall be positioned higher than the doorless ends.

**4.3.3.8** Vehicle wheels shall be chocked or secured by other equivalent means to prevent longitudinal movement of the vehicles on board a ship in adverse weather conditions.

**4.3.3.9** Vehicles with diesel engines shall not be left in gear during the voyage.

**4.3.3.10** Stowage of road vehicles shall be arranged in accordance with the following additional requirements:

- .1 the parking brakes of each vehicle or of each element of a combination of vehicles shall be applied and locked;
- .2 semi-trailers shall not be supported on their landing legs during sea transport unless the landing legs are specially designed for that purpose and so marked. An uncoupled semi-trailer shall be supported by a trestle or similar device placed in the immediate area of the coupling point so that the connection of the fifth-wheel to the kingpin is not restricted. Semi-trailer jacking-up point shall be properly reinforced and marked.

**4.3.3.11** Two patterns of roll-trailers' positioning parallel with the ship's plane of symmetry are approved:

- .1 with a gap allowing to apply lashings on the front beams;
- .2 without a gap – in that case roll-trailers stick to each other with the front beams and such an arrangement shall eliminate any damage to the elements of the front beams.

**4.3.3.12** Only one lashing, which a transport securing point on the road vehicle or roll-trailer is designed for, should be attached in such a point.

**4.3.3.13** Lashings should only be attached to the securing points provided for that purpose.

**4.3.3.14** Special consideration should be given to the securing of road vehicles stowed in positions where they may be exposed to additional forces. Where vehicles are stowed athwartship, special consideration should be given to the forces which may arise from such stowage.

**4.3.3.15** Vehicles designed to transport loads likely to have an adverse effect on their stability, such as hanging meat, should have integrated in their design a means of neutralizing the suspension system.

#### **4.4 Calculations for Lashings of Road Vehicles and Roll-trailers**

##### **4.4.1 Calculation of the Forces in the Lashing System of Road Vehicles and Roll-trailers**

**4.4.1.1** The forces resulting from the acceleration of gravity and from the accelerations induced by the ship motion on waves, the forces resulting from the elastic strain of the devices securing vehicles and roll-trailers as well as friction forces shall be taken into account in the lashing system of vehicles and roll-trailers.

**4.4.1.2** The accelerations specified in 4.4.1.1 shall be calculated in accordance with Chapter 17 of *Part II – Hull*.

**4.4.1.3** While calculating the forces, the following assumptions shall be made:

- .1 the initial stress in the lashings securing vehicles and roll-trailers is neglected, unless it exceeds 5 kN;
- .2 the forces resulting from the elastic strain of the structural elements of vehicles, roll-trailers and decks are neglected;
- .3 the centres of gravity of containers stowed on vehicles and roll-trailers are situated in their geometrical centre;
- .4 while loading general cargo onto vehicles and roll-trailers, the centres of gravity shall be determined individually for each accepted load composition, but normally not lower than at the half height of the load;
- .5 symmetrical arrangement of the vehicles in relation to the lashing points.

**4.4.1.4** Calculations of lashings of road vehicles and roll-trailers shall be made for the case of tipping in accordance with 4.4.2, whereas for the case of sliding – in accordance with 4.4.3 and 4.4.4.

**4.4.1.5** Securing devices shall be selected in relation to the obtained calculation results, in accordance with 4.4.2, 4.4.3 and 4.4.4 for the greatest value obtained from the calculations.

**4.4.1.6** The number of lashings on one side of a roll-trailer, adopted in the calculations, may not be greater than the number of the securing points provided on the respective side of a roll-trailer, exclusive of the securing points situated on the front beams of the roll-trailer. The securing points situated on the front beams of the roll-trailer may be taken into account in the calculations only in special cases and are subject to approval of PRS in each particular case.

Depending on the fact which force is greater, in the case of tipping or sliding, lashings shall be applied as shown in Fig. 4.4.1.6a or in Fig. 4.4.1.6b respectively.

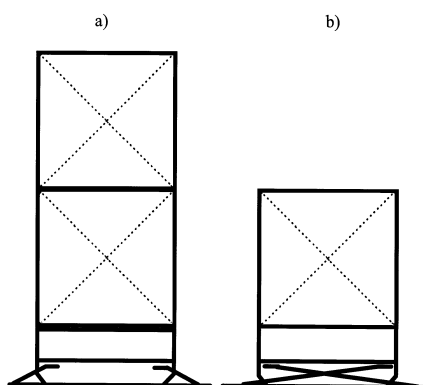


Fig. 4.4.1.6

Application of lashings in the case of tipping (a) or sliding (b) of a roll-trailer

### 4.4.2 Calculations for Securing Devices Preventing Tipping of Road Vehicles and Roll-trailers as a Result of Ship Rolling

4.4.2.1 As a result of ship rolling forces, a road vehicle or roll-trailer may tilt, i.e. turn round point A – see Fig. 4.4.2.1.

It is adopted that point A is situated on the outer edge of the outer wheel of a road vehicle or roll-trailer in the point of contact of the wheel and a deck (see Fig. 4.4.2.1a and Fig. 4.4.2.1c) or in the outer point of the edge of the surface of contact between the front beam supporting the roll-trailer or the semi trailer support with the deck (see Fig. 4.4.2.1b and Fig 4.4.2.1d).

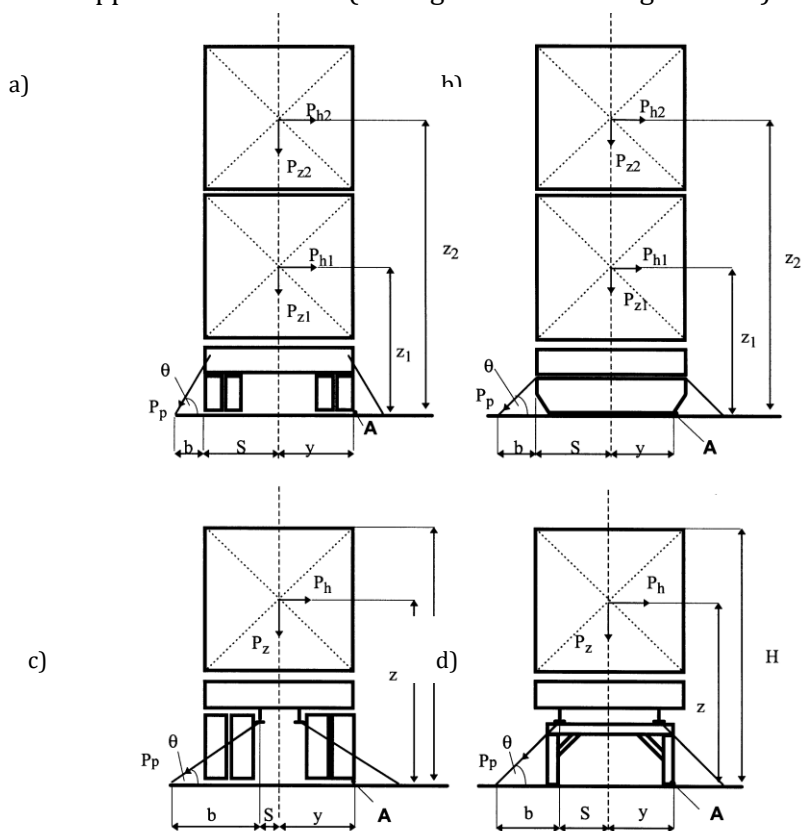


Fig. 4.4.2.1 Identification of turning point A and the distribution of forces in a container stack, lashed on a road vehicle or roll-trailer, and in the securing points of the vehicle and roll-trailer



**4.4.2.2** Magnitude of the force tipping a vehicle or roll-trailer depends on the position of the cargo centre of gravity and its mass, on the position of point A as well as on the accelerations of the centres of gravity of the specific components of the vehicle or roll-trailer in its stowage location on a ship.

**4.4.2.3** The **horizontal** force,  $P_h$  or  $P_{ha}$ , acting on a road vehicle or roll-trailer, induced by the accelerations resulting from the ship motion on waves, shall be calculated using the following formula:

$$P_h = M \cdot a_h, \text{ [kN]} \quad - \quad \text{where } M = \text{const.} \quad (4.4.2.3-1)$$

$$P_{ha} = M_a \cdot a_h, \text{ [kN]} \quad - \quad \text{where } M_a \text{ is variable or the ship turning axis intersects a stack of containers or the composition of the cargo} \quad (4.4.2.3-2)$$

where:

$M$  – mass of the container or cargo of a road vehicle or roll-trailer, etc.

$a_h$  – vertical acceleration of the centre of gravity of a container or a vehicle, equal of  $a_t$  or  $a_l$ .

**4.4.2.4** The **vertical** force,  $P_z$  or  $P_{za}$ , induced by the acceleration of gravity and the vertical acceleration  $a_v$ , resulting from the ship motion on waves, shall be calculated using the following formulae:

$$P_z = M(g - a_v), \text{ [kN]} \quad (4.4.2.4-1)$$

$$P_{za} = M_a(g - a_v), \text{ [kN]} \quad (4.4.2.4-2)$$

**4.4.2.5** The sum of tipping forces,  $P_p$  or  $P_{pa}$ , in the lashings on one side of a vehicle or roll-trailer, regardless of their rake angle, resulting from the action of the horizontal forces ( $P_h$ ) and vertical forces ( $P_z$ ), shall be calculated using the following formulae:

$$P_p = \frac{\sum_{i=1}^m P_{hi}Z_i - y \sum_{i=1}^m P_{zi}}{(y + S + b) \sin \theta}, \text{ [kN]} \quad (4.4.2.5-1)$$

$$P_{pa} = \frac{\sum_{i=1}^m P_{hai}Z_i - y \sum_{i=1}^m P_{zai}}{(y + S + b) \sin \theta}, \text{ [kN]} \quad (4.4.2.5-2)$$

**4.4.2.6** The longitudinal force,  $P_l$ , acting in one lashing, depending on the magnitude of force  $P_p$  and angle  $\gamma$  (see Fig. 4.4.2.6), between the lashing and the direction of force  $P_p$ , shall be calculated using the following formulae:

$$P_l = \frac{P_p}{k_p \cdot \cos \gamma}, \text{ [kN]} \quad (4.4.2.6-1)$$

$$P_l = \frac{P_{pa}}{k_p \cdot \cos \gamma}, \text{ [kN]} \quad (4.4.2.6-2)$$

where:

$k_p$  – number of lashings intended to be applied on each side of a vehicle. Angles  $\theta$  and  $\gamma$  as well as the procedure of their calculation are shown in Fig. 4.4.2.6.

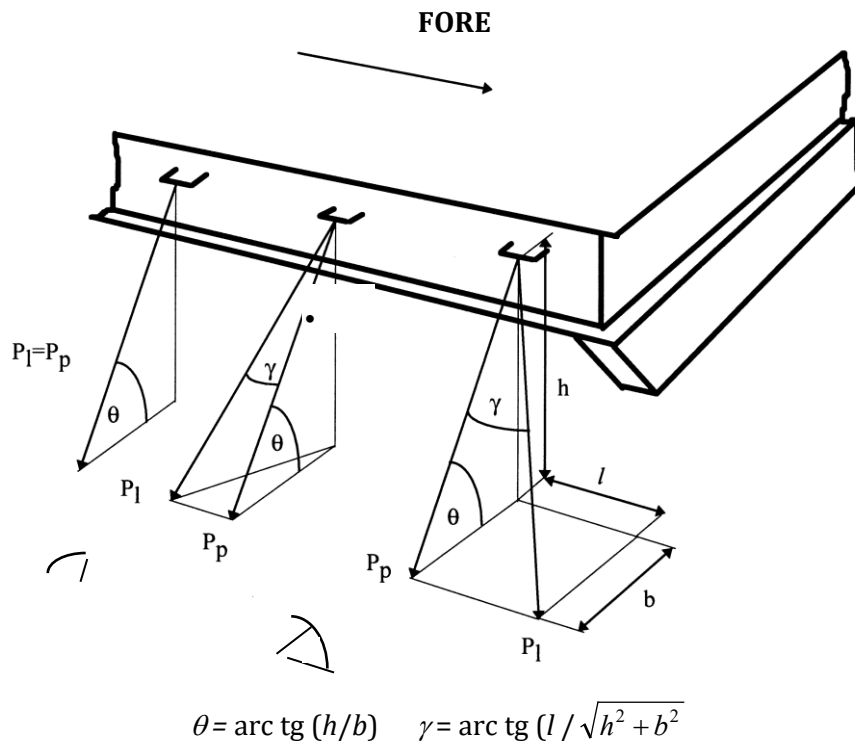


Fig. 4.4.2.6

Distribution of forces in a lashing and calculation of angles  $\theta$  and  $\gamma$

**4.4.2.7** The minimum number of lashings  $k_p$  on each side of a vehicle or roll-trailer shall be calculated using the following formula:

$$k_p \geq \frac{P_p}{MSL \cdot \cos \gamma} \tag{4.4.2.7}$$

**4.4.2.8** While calculating the lashing forces preventing tipping of a vehicle or roll-trailer, the mass of the vehicle or roll-trailer itself shall be neglected. The maximum value of angle  $\gamma_{\max}$  equal to  $60^\circ$  shall be taken into account in the calculations.

**4.4.3 Calculations of the Devices Securing Road Vehicles and Roll-trailers against Athwarship Sliding as a Result of Ship Rolling**

**4.4.3.1** Ship rolling results in the occurrence of force  $P_B$ , parallel with the deck, which is partially balanced by the force  $T$  of friction of the wheels and supports against the deck.

The distribution of forces at the moment of the ship heel is shown in Fig. 4.4.3.1.

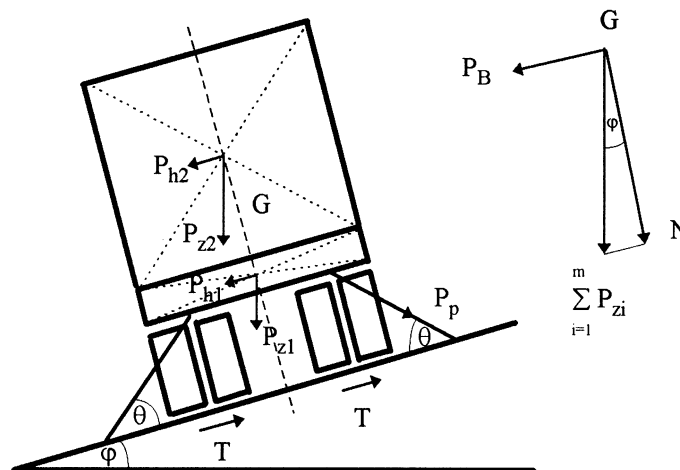


Fig. 4.4.3.1

Distribution of forces in containers lashed to a roll-trailer in the road vehicle and roll-trailer at the moment of ship heel

**4.4.3.2** The vertical force,  $P_z$  or  $P_{za}$ , shall be calculated in accordance with 4.4.2.4-1 or 4.4.2.4-2.

Pressure force  $N$  of a vehicle and roll-trailer on the deck shall be calculated using the following formulae:

$$N = \sum_{i=1}^m P_{zi} \cos \varphi + P_p \sin \theta, \text{ [kN]} \quad (4.4.3.2-1)$$

or

$$N = \sum_{i=1}^m P_{zai} \cos \varphi + P_p \sin \theta, \text{ [kN]} \quad (4.4.3.2-2)$$

$\varphi$  – heel angle.

**4.4.3.3** The parallel with the deck force,  $P_B$ , resulting in athwartship sliding of the vehicle and roll-trailer, caused by the ship heel and action of the athwartship acceleration  $a_t$  shall be calculated using the following formulae:

$$P_B = \sum_{i=1}^m P_{hi}, \text{ [kN]} \quad (4.4.3.3-1)$$

or

$$P_B = \sum_{i=1}^m P_{hai}, \text{ [kN]} \quad (4.4.3.3-2)$$

**4.4.3.4** Friction force  $T$  in the points of jacking-up of a vehicle and roll-trailer shall be calculated using the following formula:

$$T = N\mu, \text{ [kN]} \quad (4.4.3.4)$$

$\mu$  – minimum value of the coefficient of friction between the wheels and deck, the jack and deck or the jack and vehicle, which shall be selected from Table 4.4.3.4.

**Table 4.4.3.4**

Material	Coefficient of sliding friction – $\mu$		
	dry deck	oiled deck	wet deck
steel – steel	0.1	0.01	–
rubber – metal	0.5	–	0.2 ÷ 0.3
rubber – wood	0.6 ÷ 0.8	–	0.2 ÷ 0.3
wood – wood	0.2 ÷ 0.4	0.08 ÷ 0.1	0.25
metal – wood	0.2 ÷ 0.5	0.02 ÷ 0.08	0.22 ÷ 0.25

**4.4.3.5** Complete vehicle and roll-trailer kerb weights shall be taken into account in the calculations. For semi-trailers and roll-trailers supported on the wheels at one end and jacked up at the other end, friction force  $T$  shall be calculated separately for each end taking halves of the values of forces  $N$  and  $P_B$  obtained using formulae 4.4.3.2-1 (4.4.3.2-2) and 4.4.3.3-1 (4.4.3.3-2).

It is assumed that a support may slide on the deck and a vehicle or roll-trailer may slide on the support. This assumption necessitates adoption of a lower value of coefficient  $\mu$ .

**4.4.3.6** The force in one lashing which prevents athwart sliding shall be calculated using the following formula:

$$P_l = \frac{0.6P_B - \mu P_z \cos \varphi}{k_b \cdot \cos \gamma (\cos \theta + \mu \cdot \sin \theta)}, \quad [\text{kN}] \quad (4.4.3.6)$$

**4.4.3.7** The minimum number of lashings  $k_b$  on each side of a vehicle or roll-trailer shall be calculated using the following formula:

$$k_b \geq \frac{0.6P_B - \mu P_z \cdot \cos \varphi}{MSL \cdot \cos \gamma (\cos \theta + \mu \cdot \sin \theta)} \quad (4.4.3.7)$$

#### 4.4.4 Calculation of Devices Securing Road Vehicles and Roll-trailers against Fore-and-aft Sliding as a Result of Ship Pitching

**4.4.4.1** Ship pitching causes occurrence of force  $P_R$  parallel with the deck which is partially balanced by friction force  $T_L$  of the chocked wheels and supports against the deck. Distribution of these forces during the pitch is shown in Fig. 4.4.4.1.

**4.4.4.2** The vertical force,  $P_z$  or  $P_{zai}$ , shall be calculated in accordance with 4.4.2.4-1 (4.4.2.4-2). The force of compression,  $N_L$ , of a vehicle or roll-trailer on the deck shall be calculated using the following formulae:

$$N_L = \sum_{i=1}^m P_{zi} \cdot \cos \Psi, \quad [\text{kN}] \quad (4.4.4.2-1)$$

or

$$N_L = \sum_{i=1}^m P_{zai} \cdot \cos \Psi, \quad [\text{kN}] \quad (4.4.4.2-2)$$

or

$$N_L = \sum_{i=1}^m P_{zi} \cdot \cos(\Psi + \rho), \quad [\text{kN}] \quad (4.4.4.2-3)$$

or

$$N_L = \sum_{i=1}^m P_{zai} \cdot \cos(\Psi + \rho), \quad [\text{kN}] \quad (4.4.4.2-4)$$

$\rho$  – vehicle tilt angle (internal ramp)

$\Psi$  – pitching angle

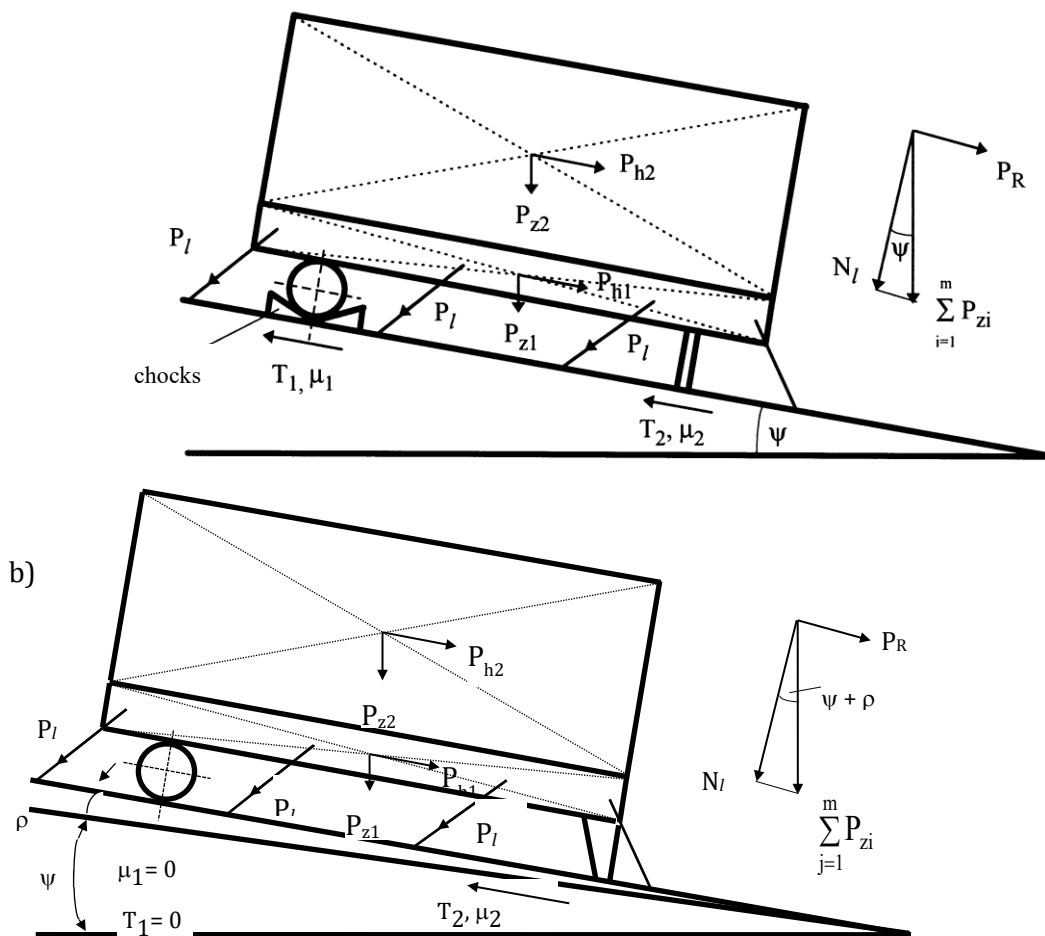


Fig. 4.4.4.1

Distribution of forces acting on container lashed on road vehicle (a) and roll-trailer (b) stowed on internal ramp

**4.4.4.3** The parallel with the deck force,  $P_R$ , which causes longitudinal sliding of a vehicle and roll-trailer and results from the ship trim increased by the possible tilt of the vehicle or roll-trailer stowage position by angle  $\rho$ , and by longitudinal acceleration  $a_1$ , shall be calculated using the following formulae:

$$P_R = \sum_{i=1}^m P_{hi}, \quad [\text{kN}] \quad (4.4.4.3-1)$$

or

$$P_R = \sum_{i=1}^m P_{hai}, \quad [\text{kN}] \quad (4.4.4.3-2)$$

**4.4.4.4** The friction force,  $T_L$ , of a road vehicle or roll-trailer against the deck shall be calculated using the following formulae:

$$T_L = 0.5N_L \cdot \mu_2, \quad [\text{kN}] \quad - \text{ where chocks are not applied} \quad (4.4.4.4-1)$$

$$T_L = 0.5N_L(\mu_1 + \mu_2), \quad [\text{kN}] \quad - \text{ where chocks are applied} \quad (4.4.4.4-2)$$

$\mu_1$  – coefficient of friction between the wheels and deck,

$\mu_2$  – coefficient of friction between the jack-up and deck or jack-up and vehicle (in accordance with 4.4.3.4).

**4.4.4.5** Complete vehicle and roll-trailer kerb weights shall be taken into account in the calculations in compliance with the requirements specified in 4.4.3.5.

**4.4.4.6** Force  $P_L$  acting in one lashing which prevents longitudinal sliding of a vehicle or roll-trailer, shall be calculated using the following formula:

$$P_L = \frac{P_R - T}{k_L \sin \gamma}, \quad [\text{kN}] \quad (4.4.4.6)$$

$k_L$  – number of lashings on both sides of a vehicle or roll-trailer preventing longitudinal sliding during the action of force  $P_R$ .

**4.4.4.7** Minimum number of lashings  $k_L$  preventing longitudinal sliding during the action of force  $P_R$  shall be calculated using the following formula:

$$k_L \geq \frac{P_R - T_L}{MSL \sin \gamma_{\min}} \quad (4.4.4.7)$$

**4.4.4.8** The minimum actual angle  $\gamma_{\min}$ , which in the case of the vehicle stowed on an internal ramp shall not exceed  $30^\circ$ , shall be taken into account in the calculations of the securing devices preventing longitudinal sliding of the vehicle.

## 5 STOWAGE AND LASHING OF TIMBER DECK CARGO

### 5.1 General Requirements and Application

**5.1.1** The requirements specified in this Chapter apply to ships who have, in their symbol of class, additional mark **TIMBER** or notation: "The ship fit for timber deck cargo carriage" in the Appendix to the Certificate of Class.

### 5.2 Definitions

**5.2.1** Timber deck cargo – a cargo of timber carried on an uncovered part of a freeboard or superstructure deck. The term does not include wood pulp or similar cargo.

**5.2.2** Timber – sawn wood or lumber, cants, poles, pulpwood and all other type of timber in loose or packaged forms. The term does not include wood pulp or similar cargo.

**5.2.3** Timber load line - a special load line assigned to ships complying with certain conditions set out in the International Convention on Load Lines.

### 5.3 Technical Survey

**5.3.1** The technical survey PRS covers the equipment, fittings and other deck stowage and lashing devices for securing of timber deck cargo where any part of the volume of the timber deck cargo has been taken into account in the calculations of the ship cross curves.

**5.3.2** Both fixed and portable lashing equipment for securing of timber deck cargo shall fulfil the requirements specified in Chapter 2 of this *Publication*.

## 5.4 Scope of Survey

**5.4.1** Surveys of the stowage and lashing equipment for timber deck cargo shall be performed in accordance with paragraphs 2.2.3 and 2.2.4 of this Publication.

**5.4.2** In addition to the surveys specified in 5.4.1, the survey of the fixed securing devices for timber deck cargo shall be performed before loading in each particular case which is the responsibility of the Shipowner.

## 5.5 Stability

**5.5.0** The Master shall ensure that the ship condition complies with its stability booklet at all times.

**5.5.1** Ships carrying timber deck cargo shall continue to fulfil the relevant damage stability requirements (e.g. *SOLAS* regulation II-1/4.1 or *Load Lines Convention*, regulation 27, as appropriate) and, additionally, the *2008 IS Code*, particularly the timber deck cargo requirements. Since excessive GM values induce large accelerations, GM shall preferably not exceed 3% of the breadth of the vessel, as indicated in paragraph 3.7.5 of the *2008 IS Code*.

**5.5.2** Ballast water exchange operations shall be performed in accordance with the instructions contained in the Ballast Water Management Plan, if available. The ballast water exchange operation, if required, shall be considered when planning the amount of cargo to be loaded on deck.

**5.5.3** According to the *2008 IS Code*, account may be taken of the buoyancy of timber deck cargo when calculating stability curves, assuming that such cargo has a 25% permeability. Permeability is defined as the percentage of empty space of the volume occupied by the deck cargo. Additional curves of stability may be required if the Administration considers it necessary to investigate the influence of different permeabilities and/or assumed effective height of the deck cargo. 25% permeability corresponds to sawn wood cargo and 40%-60% permeability corresponds to round wood cargo with increasing permeability with increasing log diameters.

**5.5.4** The ship shall be supplied with comprehensive stability information which takes into account timber deck cargo. Such information shall enable the master to rapidly and simply obtain accurate guidance as to the stability of the ship under varying conditions of service, and as required in *SOLAS Regulation II-1/5-1* it shall include, among other damage stability related issues, a curve of minimum operating metacentric height (GM) versus draught or maximum allowable vertical centre of gravity (KG) versus draught which covers the requirements of *SOLAS Regulation II-1/5-1.2.1*.

**5.5.5** For ships loaded with timber deck cargo, intended to be operated in areas, in which icing shall not be taken into account, as well as those navigating in summer within winter seasonal zones, the stability shall be calculated for the most unfavourable loading condition fulfilling the requirements specified in paragraph 3.5 of Part IV *Stability and subdivision of the Rules for the classifications and construction of sea-going ships*, having regard to the possible increase of the timber deck cargo due to water absorption.

Calculations of the change of timber cargo mass due to water absorption shall be made in accordance with Annex C to *Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 2011*.

Where data on the extent of water absorption by different kinds of timber are not available, it is recommended that the increase in mass of the deck cargo should be assumed equal to 10%.

The increase in mass shall be regarded as a mass additional to the ship deadweight. It is assumed that the centre of mass of timber deck cargo does not change due to water absorption.

**5.5.6** Unless instructed otherwise by the Administration, the stability information for ships with timber deck cargoes shall be supplemented by additional curve(s) of limiting GM (or KG) covering the timber draught range. The curve(s) of limiting GM (or KG) applicable for conditions with timber deck cargo is/are to be developed as described in SOLAS Regulation II-1/5-1.4, and considering timber deck cargo at the deepest timber subdivision draught and at the partial timber subdivision draught only.

**5.5.7** The limiting GM shall be varied linearly between the deepest timber subdivision draught, and between the partial timber subdivision draught and the light service draught respectively.

**5.5.8** Where timber freeboards are not assigned the deepest and partial draughts shall relate to the summer load line.

## **5.6 Stowage**

**5.6.1** The basic principle for the safe carriage of timber deck cargo is to make the stow as solid, compact and stable as practicable. The purpose of this is to:

- prevent movement in the stow which could cause the lashings to slacken;
- produce a binding effect within the stow; and
- reduce to a minimum the permeability of the stow.

**5.6.2** Openings in the deck exposed to weather over which cargo is stowed shall be reliably closed and battened down. The ventilators and air pipes shall be effectively protected.

**5.6.3** Deck cargo shall be stowed so that access is provided to and from designated escape routes and spaces essential to operation of the vessel, such as machinery spaces and crew's quarters, as well as to safety equipment, fire-fighting equipment and sounding pipes. It shall not interfere in any way with the navigation and necessary work on the ship.

**5.6.4** The height and extent of the timber deck cargo shall be in accordance with 3.3.2 of Chapter 3, Part A of the International Code on Intact Stability, 2008 and shall be at least stowed to the standard height of one superstructure.

**5.6.5** To ensure the buoyancy of timber deck cargo can be justifiably credited in damage stability calculations, the integrity of the lashed timber deck cargo shall comply with the following:

- .1** The timber deck cargo is to be stowed in accordance with the requirements of 2.9 of the *Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 2011* (Resolution A.1048(27)).
- .2** The timber deck cargo is to be secured by lashings and/or uprights in accordance with the requirements of 2.10 of the *Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 2011* (Resolution A.1048(27)).

## **5.7 Alternative Design Principles for Securing Devices**

**5.7.1** The required features of securing devices are given in Chapter 5 of Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 2011.

**5.7.2** It is permitted to use designs and securing arrangements alternative to those mentioned in 5.7.1 for ships of less than 24 m in beam.

The construction of deck, bulwarks, uprights, hatches and coamings shall be of design that allows a load of timber deck cargo to be carried in a satisfactory manner (see Chapter 6 of *Code of Safe Practice for Ships Carrying Timber Deck Cargoes, 2011*).



## ANNEX 3

### GUIDANCE ON PROVIDING SAFE WORKING CONDITIONS FOR SECURING OF CONTAINERS ON DECK

#### 1 AIM

To ensure that persons engaged in carrying out container securing operations on deck have safe working conditions and, in particular safe access, appropriate securing equipment and safe places of work. These guidelines shall be taken into account at the design stage when securing systems are devised. These guidelines provide guidance on producing or authorizing a Cargo Safe Access Plan (CSAP).

#### 2 SCOPE

**2.1** This annex applies in its entirety to ships which are specifically designed and fitted for the purpose of carrying containers on deck, the keels of which were laid or which are at a similar stage of construction on or after 1 January 2015.

**2.2** Section 7.3 (Maintenance) and section 8 (Specialized container safety design) apply to existing containerships, the keels of which were laid or which are at a similar stage of construction before 1 January 2015.

**2.3** The principles of this guidance contained in section 6 (Design) apply to existing containerships as far as practicable with the understanding that existing ships would not be required to be enlarged or undergo other major structural modifications as determined.

#### 3 DEFINITIONS

**3.1** Fencing is a generic term for guardrails, safety rails, safety barriers and similar structures that provide protection against the falls of persons.

**3.2** Lashing positions include positions:

- .1 in between container stows on hatch covers;
- .2 at the end of hatches;
- .3 on outboard lashing stanchions/pedestals;
- .4 outboard lashing positions on hatch covers; and
- .5 any other position where people work with container securing.

**3.3** SATLs are semi-automatic twistlocks.

**3.4** Securing includes lashing and unlashings.

**3.5** Stringers are the uprights or sides of a ladder.

**3.6** Turnbuckles and lashing rods<sup>2</sup> include similar cargo securing devices.

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<sup>2</sup> Refer to standard ISO 3874, Annex D Lashing rod systems and tensioning devices.

## 4 GENERAL

### 4.1 Introduction

**4.1.1** Injuries to dockworkers on board visiting ships account for the majority of accidents that occur within container ports, with the most common activity that involves such injuries being the lashing/unlashing of deck containers. Ships' crew engaged in securing operations face similar dangers.

**4.1.2** During the design and construction of containerships the provision of a safe place of work for lashing personnel is essential.

**4.1.3** Container shipowners and designers are reminded of the dangers associated with container securing operations and urged to develop and use container securing systems which are safe by design. This aims to eliminate or at least minimize the need for:

- .1 container top work;
- .2 work in other equally hazardous locations; and
- .3 the use of heavy and difficult to handle securing equipment.

**4.1.4** It shall be borne in mind that providing safe working conditions for securing containers deals with matters relating to design, operation, and maintenance, and that the problems on large containerships are not the same as on smaller ones.

**4.2** Shipowners and ship designers shall take into account the recommendations on safe design of securing arrangements contained in these Guidelines, and in the *Revised Recommendations on Safety of Personnel during Container Securing Operations* (MSC.1/Circ.1263).

### 4.3 Cargo Safe Access Plan (CSAP)

**4.3.1** The *Guidelines for Preparation of Cargo Securing Manual* (MSC/Circ.745) require ships which are specifically designed and fitted for the purpose of carrying containers to have an approved *Cargo Safe Access Plan* (CSAP) on board, for all areas where containers are secured.

**4.3.2** Stakeholders, including, but not limited to shipowners, ship designers, ship builders, administrations, classification societies and lashing equipment manufacturers, shall be involved at an early stage in the design of securing arrangements on containerships and in the development of the CSAP.

**4.3.3** The CSAP shall be developed at the design stage in accordance with Chapter 5 of the Annex to MSC.1/Circ.1353/Rev.2.

**4.3.4** Designers shall incorporate the recommendations of this annex into the CSAP so that safe working conditions can be maintained during all anticipated configurations of container stowage.

## 5 RESPONSIBILITIES OF INVOLVED PARTIES

**5.1** PRS verifies whether:

- .1 lashing plans contained within the approved Cargo Securing Manual are compatible with the current design of the ship and the intended container securing method is both safe and physically possible;
- .2 the Cargo Securing Manual, lashing plans and the CSAP are kept up to date; and
- .3 lashing plans and the CSAP are compatible with the design of the ship and the equipment available.

- 5.2** Shipowners and operators shall ensure that:
- .1** portable cargo securing devices are certified and assigned with a maximum securing load (MSL). The MSL shall be documented in the cargo securing manual as required by the CSS Code;
  - .2** correction, changes or amendments of the Cargo Securing Manual, lashing plans and the Cargo Safe Access Plan (CSAP) shall be promptly sent to the competent authority for approval; and
  - .3** only compatible and certified equipment in safe condition is used.
- 5.3** Designers shall follow design recommendations of these guidelines.
- 5.4** Shipbuilders shall follow design recommendations of these guidelines.

## **6 DESIGN**

### **6.1 General design considerations**

#### **6.1.1 Risk Assessment**

**6.1.1.1** Risk assessments shall be performed at the design stage taking into account the recommendations of this annex to ensure that securing operations can be safely performed in all anticipated container configurations. This assessment shall be conducted with a view toward developing the Cargo Safe Access Plan (CSAP).

Hazards to be assessed shall include but not be limited to:

- .1** slips, trips and falls;
- .2** falls from height;
- .3** injuries whilst manually handling lashing gear;
- .4** being struck by falling lashing gear or other objects;
- .5** potential damage due to container operations. High-risk areas shall be identified in order to develop appropriate protection or other methods of preventing significant damage;
- .6** adjacent electrical risks (temperature controlled unit cable connections, etc.);
- .7** the adequacy of the access to all areas that is necessary to safely perform container securing operations;
- .8** ergonomics (e.g., size and weight of equipment) of handling lashing equipment; and
- .9** implications of lashing 9'6" high, or higher, containers and mixed stows of 40' and 45' containers.

**6.1.1.2** Shipbuilders shall collaborate with designers of securing equipment in conducting risk assessments and ensure that the following basic criteria are adhered to when building containerships.

**6.1.2** Ship designers shall ensure that container securing operations performed in outer positions can be accomplished safely. As a minimum, a platform shall be provided on which to work safely. This platform shall have fencing to prevent workers falling off it.

**6.1.3** The space provided between the containers stows for workers to perform lashing operations shall provide:

- .1** a firm and level working surface;
- .2** a working area, excluding lashings in place, to provide a clear sight of twist lock handles and allow for the manipulation of lashing gear;

- .3 sufficient spaces to permit the lashing gear and other equipment to be stowed without causing a tripping hazard;
- .4 sufficient spaces between the fixing points of the lashing bars on deck, or on the hatch covers, to tighten the turnbuckles;
- .5 access in the form of ladders on hatch coamings;
- .6 safe access to lashing platforms;
- .7 protective fencing on lashing platforms; and
- .8 adequate lighting in line with these guidelines.

**6.1.4** Ship designers shall aim to eliminate the need to access and work on the tops of deck stows.

**6.1.5** Platforms shall be so designed to provide a clear work area, unencumbered by deck piping and other obstructions and take into consideration:

- .1 containers must be capable of being stowed within safe reach of the workers using the platform; and
- .2 the work area size and the size of the securing components used.

## **6.2 Provisions for Safe Access**

### **6.2.1 General Provisions**

**6.2.1.1** The minimum clearance for transit areas shall be at least 2 m high and 600 mm wide.

**6.2.1.2** All relevant deck surfaces used for movement about the ship and all passageways and stairs shall have non-slip surfaces.

**6.2.1.3** Where necessary for safety, walkways on deck shall be delineated by painted lines or otherwise marked by pictorial signs.

**6.2.1.4** All protrusions in access ways, such as cleats, ribs and brackets that may give rise to a trip hazard shall be highlighted in a contrasting colour.

### **6.2.2 Lashing position design (platforms, bridges and other lashing positions)**

**6.2.2.1** Lashing positions shall be designed to eliminate the use of three high lashing bars and be positioned in close proximity to lashing equipment stowage areas. Lashing positions shall be designed to provide a clear work area which is unencumbered by deck piping and other obstructions and take into consideration:

- .1 the need for containers to be stowed within safe reach of the personnel using the lashing position so that the horizontal operating distance from the securing point to the container does not exceed 1,100 mm and not less than 220 mm for lashing bridges and 130 mm for other positions;
- .2 the size of the working area and the movement of lashing personnel; and
- .3 the length and weight of lashing gear and securing components used.

**6.2.2.2** The width of the lashing positions shall preferably be 1,000 mm, however not less than 750 mm.

**6.2.2.3** The width of permanent lashing bridges shall be:

- .1 750 mm between top rails of fencing; and
- .2 a clear minimum of 600 mm between storage racks, lashing cleats and any other obstruction.

**6.2.2.4** Platforms on the end of hatches and outboard lashing stations shall preferably be at the same level as the top of the hatch covers.

**6.2.2.5** Toe boards (or kick plates) shall be provided around the sides of elevated lashing bridges and platforms to prevent securing equipment from falling and injuring people. Toe boards shall preferably be 150 mm high, however, where this is not possible they shall be at least 100 mm high.

**6.2.2.6** Any openings in the lashing positions through which people can fall shall be possible to be closed.

**6.2.2.7** Lashing positions shall not contain obstructions, such as storage bins or guides to reposition hatch covers.

**6.2.2.8** Lashing positions which contain removable sections shall be capable of being temporarily secured.

### **6.2.3 Fencing Design**

**6.2.3.1** Bridges and platforms, where appropriate, shall be fenced. As a minimum. Fencing design shall take into consideration:

- .1 the strength and height of the rails shall be so designed as to prevent workers from falling;
- .2 flexibility in positioning the fencing of gaps. A horizontal unfenced gap shall not exceed 300 mm;
- .3 provisions for locking and removal of fencing as operational situations change based on stowage anticipated for that area;
- .4 damage to fencing and how to prevent failure due to that damage; and
- .5 adequate strength of any temporary fittings. These shall be capable of being safely and securely installed.

**6.2.3.2** The top rail of fencing shall be 1 m high from the base, with two intermediate rails. The opening below the lowest course of the guard rails shall not exceed 230 mm. The other courses shall not be more than 380 mm apart.

**6.2.3.3** Where possible fences and handrails shall be highlighted with a contrasting colour to the background.

**6.2.3.4** Athwartships cargo securing walkways shall be protected by adequate fencing if an unguarded edge exists when the hatch cover is removed.

### **6.2.4 Ladder and Manhole Design**

**6.2.4.1** Where a fixed ladder gives access to the outside of a lashing position, the stringers shall be connected at their extremities to the guardrails of the lashing position, irrespective of whether the ladder is sloping or vertical.

**6.2.4.2** Where a fixed ladder gives access to a lashing position through an opening in the platform, the opening shall be protected with either a fixed grate with a lock back mechanism, which can be closed after access, or fencing. Grabrails shall be provided to ensure safe access through the opening.

**6.2.4.3** Where a fixed ladder gives access to a lashing position from the outside of the platform, the stringers of the ladder shall be opened above the platform level to give a clear width of 700 to 750 mm to enable a person to pass through the stringers.

**6.2.4.4** Fixed ladder shall not slope at an angle greater than 25° from the vertical. Where the slope of a ladder exceeds 15° from the vertical, the ladder shall be provided with suitable handrails not less than 540 mm apart, measured horizontally.

**6.2.4.5** A fixed vertical ladder of a height exceeding 3 m, and any fixed vertical ladder, from which a person may fall into a hold, shall be fitted with guard hoops in accordance with the requirements specified in paragraphs 6.2.4.6 and 6.2.4.7.

**6.2.4.6** The ladder hoops shall be uniformly spaced at intervals not exceeding 900 mm and shall have a clearance of 750 mm from the rung to the back of the hoop and be connected by longitudinal strips secured to the inside of the hoops, each equally spaced round the circumference of the hoop.

**6.2.4.7** The stringers shall be carried above the floor level of the platform by at least 1 m and the ends of the stringers shall be given lateral support and the top step or rung shall be level with the floor of the platform unless the steps or rungs are fitted to the ends of the stringers.

**6.2.4.8** As far as practicable, access ladders and walkways, and work platforms shall be so designed that workers do not have to climb over piping or work in areas with permanent obstructions.

**6.2.4.9** There shall be no unprotected openings in any part of the workplace. Access opening must be protected with handrails or access covers that can be locked back during access.

**6.2.4.10** As far as practicable, manholes shall not be situated in transit areas, however, if they are, proper fencing shall protect them.

**6.2.4.11** Access ladders and manholes shall be large enough for persons to safely enter and leave.

**6.2.4.12** A foothold at least 150 mm deep shall be provided.

**6.2.4.13** Handholds shall be provided at the top of the ladder to enable safe access to the platform to be gained.

**6.2.4.14** Manhole openings that may present a fall hazard shall be highlighted in contrasting colour around the rim of the opening.

**6.2.4.15** Manhole openings at different levels of the lashing bridge shall not be located directly below one another, as far as practicable.

## **6.3 Lashing systems**

### **6.3.1 General Provisions**

Lashing systems, including tensioning devices, should:

- .1** conform to international standards<sup>3</sup>, where applicable;
- .2** be compatible with the planned container stowages;

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<sup>3</sup> Refer to standard ISO 3874 . The Handling and Securing of Type 1 Freight Containers, annex A-D.

- .3 be compatible with the physical ability of persons to safely hold, deploy and use such equipment;
- .4 be uniform and compatible, e.g., twistlocks and lashing rod heads shall not interfere with each other;
- .5 be subject to a periodic inspection and maintenance regime. Non-conforming items shall be segregated for repair or disposal; and
- .6 be according to the CSM.

### **6.3.2 Twistlock Design**

**6.3.2.1** Shipowners shall ensure that the number of different types of twistlocks provided for cargo securing is kept to a minimum and clear instructions are provided for their operation. The use of too many different types of twistlocks may lead to confusion as to whether the twistlocks are locked.

**6.3.2.2** The design of twistlocks shall ensure the following:

- .1 positive locking with easy up and down side identification;
- .2 dislodging from corner fitting is not possible even when grazing a surface;
- .3 access and visibility of the unlocking device is effective in operational situations;
- .4 unlocked positions are easily identifiable and do not relock inadvertently due to jolting or vibration; and
- .5 unlocking poles are as light as possible, of a simple design for ease of use.

**6.3.2.3** Where it is not feasible to entirely eliminate working on the tops of container stows, the twistlock designs used shall minimize the need for such working, e.g., use of SATLs, fully automatic twistlocks or similar design.

### **6.3.3 Lashing Rod Design**

**6.3.3.1** The design of containership securing systems shall take into account the practical abilities of the workers to lift, reach, hold, control and connect the components called for in all situations anticipated in the cargo securing plan.

**6.3.3.2** The maximum length of a lashing rod shall be sufficient to reach the bottom corner fitting of a container on top of two high cube containers and be used in accordance with the instructions provided by the manufacturers.

**6.3.3.3** The weight of lashing rods shall be minimized as low as possible consistent with the necessary mechanical strength.

**6.3.3.4** The head of the lashing rod that is inserted in the corner fitting shall be designed with a pivot/ hinge or other appropriate device so that the rod does not come out of the corner fitting accidentally.

**6.3.3.5** The rod's length in conjunction with the length and design of the turnbuckle shall be such that the need of extensions is eliminated when lashing high cube (9'6") containers.

**6.3.3.6** Lightweight rods shall be provided where special tools are needed to lash high cube containers.

### **6.3.4 Turnbuckle Design**

**6.3.4.1** Turnbuckle end fittings shall be designed to harmonize with the design of lashing rods.



**6.3.4.2** Turnbuckles shall be designed to minimize the work in operating them.

**6.3.4.3** Anchor points for turnbuckles shall be positioned to provide safe handling and to prevent the bending of rods.

**6.3.4.4** To prevent hand injury during tightening or loosening motions, there shall be a minimum distance of 70 mm between turnbuckles.

**6.3.4.5** The turnbuckle shall incorporate a locking mechanism which will ensure that the lashing does not work loose during the voyage.

**6.3.4.6** The weight of turnbuckles shall be minimized as low as possible consistent with the necessary mechanical strength.

### **6.3.5 Storage Bins and Lashing Equipment Stowage Design**

**6.3.5.1** Bins or stowage places for lashing materials shall be provided.

**6.3.5.2** All lashing gear shall be stowed as close to its intended place of use as possible.

**6.3.5.3** The stowage of securing devices shall be arranged so they can easily be retrieved from their stowage location.

**6.3.5.4** Bins for faulty or damaged gear shall also be provided and appropriately marked.

**6.3.5.5** Bins shall be of sufficient strength.

**6.3.5.6** Bins and their carriers shall be designed to be lifted off the vessel and restowed.

## **6.4 Lighting Design**

Lighting plan shall be developed to provide for:

- .1 the proper illumination of access ways, not less than 10 lux (1 foot candle)<sup>4</sup>, taking into account the shadows created by containers that may be stowed in the area to be lit, for example different length containers in or over the work area;
- .2 a separate fixed or temporary (where necessary) lighting system for each working space between the container bays, which is bright enough, not less than 50 lux (5 foot candle)\*, for the work to be done, but minimizes glare to the deck workers;
- .3 such illumination should, where possible, be designed as a permanent installation and adequately guarded against breakage; and
- .4 the illumination intensity shall take into account the distance to the uppermost reaches where cargo securing equipment is utilized.

## **7 MAINTENANCE PROCEDURES**

**7.1** In line with section 2.3 (Inspection and maintenance schemes) of the Revised Guidelines for the preparation of the cargo securing manual (MSC.1/Circ.1353) all ships shall maintain a record book, which should contain the procedures for accepting, maintaining and repairing or rejecting of cargo securing devices. The record book shall also contain a record of inspections.

**7.2** Lighting shall be properly maintained.

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<sup>4</sup> Refer to Safety and Health in Ports, ILO Code of Practice, section 7.1.5.



**7.3** Walkways, ladders, stairways and fencings shall be subject to a periodic maintenance programme which will reduce/prevent corrosion and prevent subsequent collapse.

**7.4** Corroded walkways, ladders, stairways and fencings shall be repaired or replaced as soon as practicable. The repairs shall be effected immediately if the corrosion could prevent safe operations.

**7.5** It shall be borne in mind that turnbuckles covered with grease are difficult to handle when tightening.

**7.6** Storage bins and their carriers shall be maintained in a safe condition.

## **8 SPECIALIZED CONTAINER SAFETY DESIGN**

**8.1** Temperature controlled unit power outlets shall provide a safe, watertight electrical connection.

**8.2** Temperature controlled unit power outlets shall feature a heavy duty, interlocked and circuit breaker protected electrical power outlet. This shall ensure the outlet can not be switched "live" until a plug is fully engaged and the actuator rod is pushed to the "On" position. Pulling the actuator rod to the "Off" position shall manually de-energize the circuit.

**8.3** The temperature controlled unit power circuit shall de-energize automatically if the plug is accidentally withdrawn while in the "On" position. Also, the interlock mechanism shall break the circuit while the pin and sleeve contacts are still engaged. This provides total operator safety and protection against shock hazard while eliminating arcing damage to the plug and receptacle.

**8.4** Temperature controlled unit power outlets shall be designed to ensure that the worker is not standing directly in front of the socket when switching takes place.

**8.5** The positioning of the temperature controlled unit feed outlets shall not be such that the flexible cabling needs to be laid out in such a way as to cause a tripping hazard.

**8.6** Stevedores or ship's crew who are required to handle temperature controlled unit cables and/or connect and disconnect reefer units shall be given training in recognizing defective wires and plugs.

**8.7** Means or provisions shall be provided to lay the temperature controlled unit cables in and protect them from lashing equipment falling on them during lashing operations.

**8.8** Defective or inoperative temperature controlled unit plugs/electrical banks shall be identified and confirmed as "locked out/tagged out" by the vessel.

## **9 REFERENCES**

*ILO Code of Practice – Safety and Health in Ports*

*ILO Convention 152 – Occupational Safety and Health in Dock Work*

*ISO Standard 3874 – The Handling and Securing of Type 1 Freight Containers*

*International Convention on Load Lines, 1966, as modified by the 1988 LL Protocol*

*Revised Recommendation on Safety of Personnel during Container Securing Operations (MSC.1/Circ.1263)*

*Revised Guidelines for the Preparation of the Cargo Securing Manual (MSC.1/Circ.1353)."*

*Revised Guidelines for the preparation of the Cargo Securing Manual (MSC.1/Circ.1353/Rev.2)."*



**SUPPLEMENT****DIMENSIONS OF CONTAINER SECURING ARRANGEMENTS**

Dimension (see respective Figures)	Description	Requirement [mm]
A	Width of work area between container stacks	≥ 750
B	Distance between lashing plates on deck or on hatch covers	≥ 600
C1	Distance from lashing bridge fencing to container stack	≥ 1100
C2	Distance from lashing plate to container stack (lashing bridge)	≥ 220
C3	Distance from lashing plate to container stack (elsewhere)	≥ 130
F	Width of lashing bridge between top rails of fencing	≥ 750
F1	Width of lashing bridge between storage racks, lashing cleats and any other obstruction	≥ 600
GL	Width of working platform for outboard lashing – fore/aft	≥ 750
GT	Width of working platform for outboard lashing – transverse	≥ 750
I	Width of work platform at end of hatch cover or adjacent to superstructure	≥ 750
J	Distance from edge of hatch cover to fencing	≥ 600
K	Width of lashing bridge between top rails of fencing	≥ 750
K1	Width of lashing bridge between the pillars of the lashing bridge	≥ 600

**NOTES**

- B – Measured between the centers of the lashing plates.  
 C1 – Measured from inside of fencing.  
 C2, C3 – Measured from centre of lashing plate to end of container.  
 F, K – Measured to inside of fencing.  
 GL – Measured from end of container to inside of fencing.  
 GT – Measured to inside of fencing.  
 I – Measured to inside of fencing.  
 J – Measured to inside of fencing.

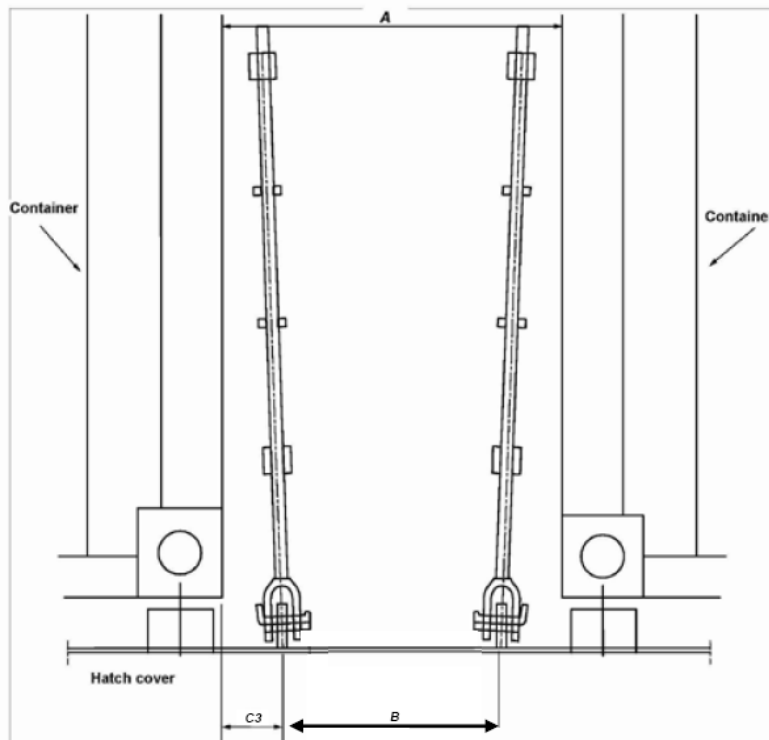


Fig. 1

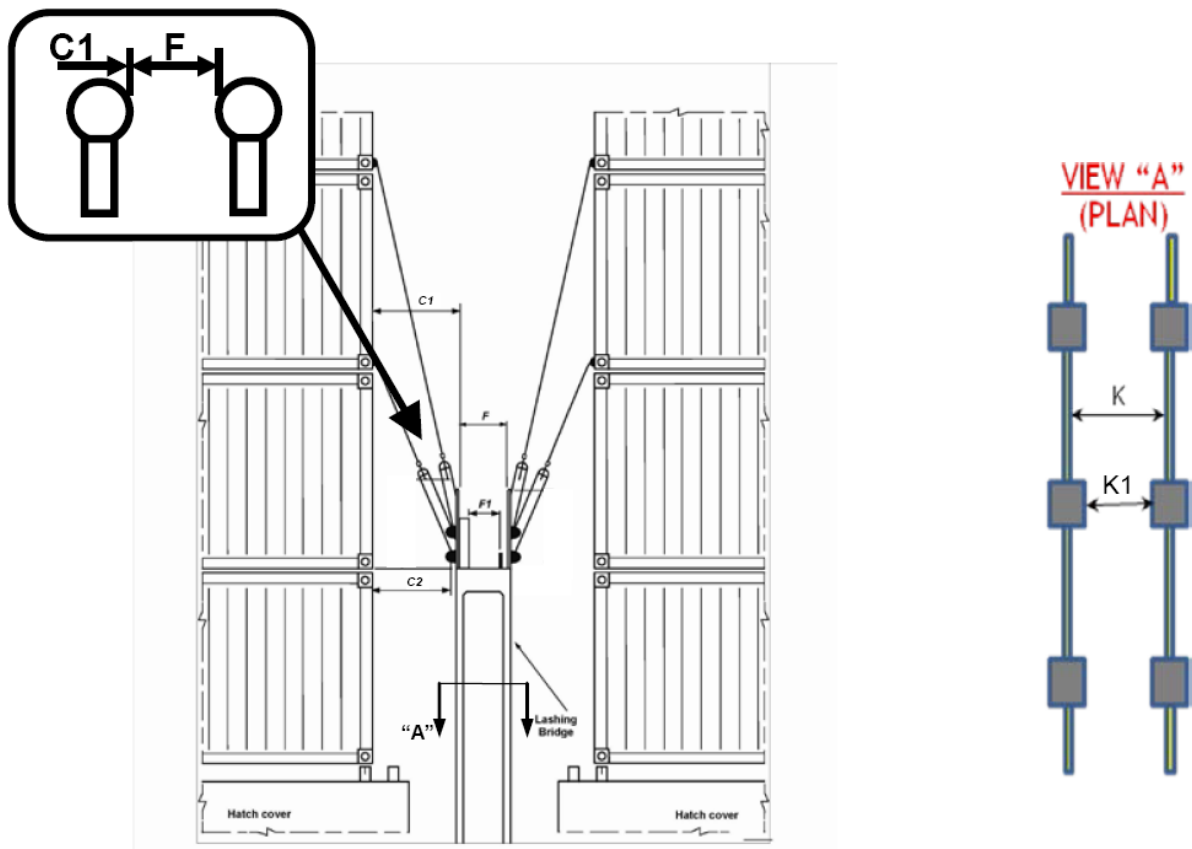


Fig. 2

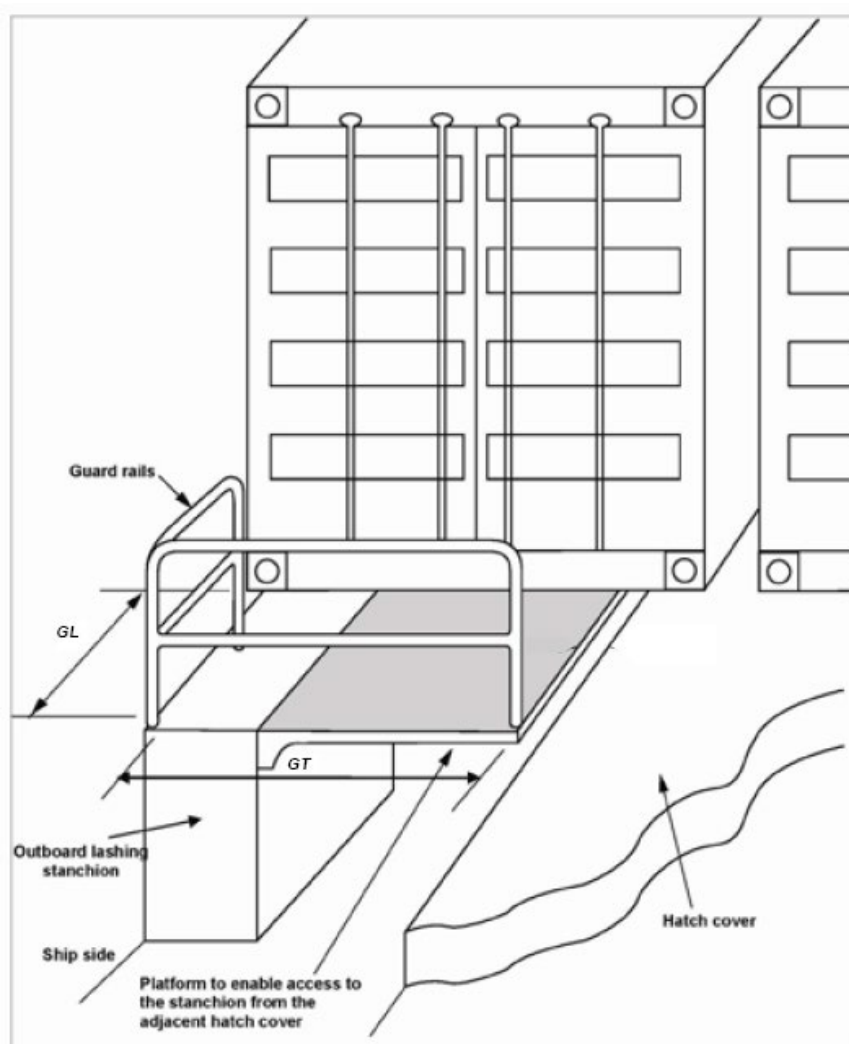


Fig. 3

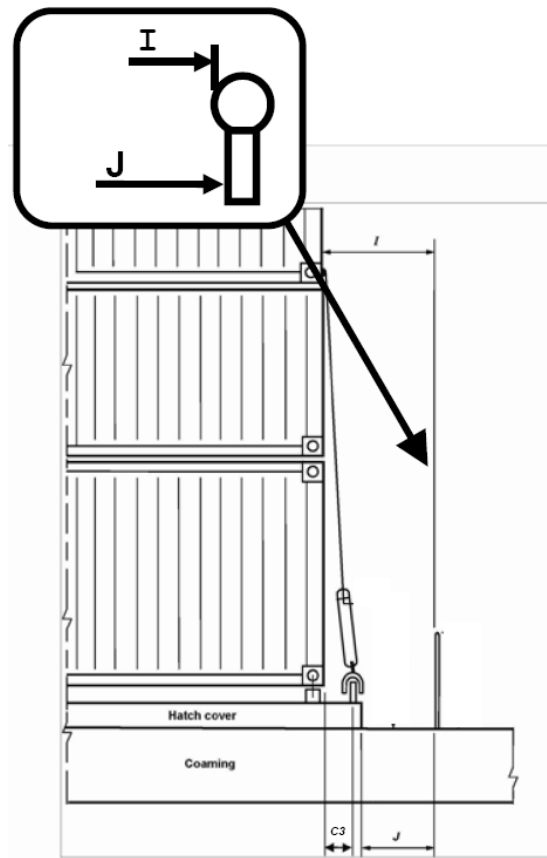


Fig. 4

**List of changes effective as of 1 January 2023**

<i>Item</i>	<i>Title/Subject</i>	<i>Source</i>
<a href="#">5.1.2</a>	Item deleted; superseded by 5.6.5	
<a href="#">5.2.3</a>	Definition	IACS UI SC 161
<a href="#">5.5.4</a>	<i>Stability information</i>	IACS UI SC 161
<a href="#">5.5.5</a>	<i>Paragraph was turned into a reference to the regulations</i>	
<a href="#">5.5.6</a>	<i>Limiting GM (KG) Curve requirements</i>	IACS UI SC 161
<a href="#">5.5.7</a>	<i>Limiting GM (KG) Curve requirements</i>	IACS UI SC 161
<a href="#">5.5.8</a>	<i>Limiting GM (KG) Curve requirements</i>	IACS UI SC 161
<a href="#">5.6.4</a>	<i>Lashing and securing requirements</i>	IACS UI SC 161
<a href="#">5.6.5</a>	<i>Lashing and securing requirements</i>	IACS UI SC 161