BBC Chartering®

BBC Guideline

Safe Solutions for Project Cargo Operations

Version 1.0

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Introduction

The BBC Guideline for Project Cargo Operations has been prepared to serve several purposes as follows:

- To provide guidance to masters and officers of ships engaged by BBC Chartering for handling, bedding and securing of project cargo units and other non-standardized cargo.
- To provide guidance to Port Captains and other technical personnel for handling and planning of project cargo units and other non-standardized cargo.
- To serve as background information and training material for junior officers, port captains and other technical personnel working for BBC Chartering.
- To offer customers the opportunity to verify the performance of BBC Chartering in regards to technical standards and the application of good seamanship in project cargo operations.

All provisions and instructions contained in this Guideline conform to international regulations and recommendations, in particular with the IMO Code of Safe Practice for Cargo Stowage and Securing in its current 2009 edition. Units and symbols used correspond to the Système International d'Unités (SI-units).

The BBC Guideline further complies with provisions contained in other official documents of BBC Chartering. It will, in particular, provide guidance to the interpretation of, but not override the approved Cargo Securing Manuals of specific ships.

Whilst the BBC Guideline offers a safe solution for handling project cargo, in special cases there might be customer requirements that require additional lashings and a lower friction factor. If this is the case this will be specified in the planning process.

BBC will not accept under any circumstances whatsoever, any variation from the methods set in this Guideline, which would result in lower safety in regards to cargo handling and securing. Where any variation from the methods is deemed necessary, the methods in this Guideline should be viewed as minimum requirements.

If required, the bedding principles outlined in chapter 2 provide a safe methodology for distributing the weight of cargo items whilst maintaining the safe structure of the vessel.

During pre-planning, these principles might be overruled and bedding undertaken by another means if an in-depth calculation demonstrates that an alternative method is safe.

In principle, all shipments of heavy and/or sensitive project cargo units are pre-planned by BBC Chartering. The technical shipping procedures are in some cases laid down in a "loading manual", which is provided to the master of the vessel. This does not limit in any way the responsibility of the master for the appropriate application of all relevant procedures. The master has the overriding authority to deviate from the "loading manual" if the safety situation or nature of cargo requires this. BBC Chartering should always be contacted if a change to the planned operation is required. If there is a 3rd party surveyor present and BBC is obliged by contract to seek his approval of procedures, the field staff must obtain written confirmation from the surveyor in attendance that the changes have been agreed.

The principle above also applies to instructions given in this Guideline. Where no instruction, recommendation or technical rule is provided, the reader should support the master who is responsible and obligated to take deviating decisions if the safety of personnel, cargo or vessel so demands. Safety is always our highest priority.

Any person using this Guideline as a reference who has any questions relating to this Guideline, or has any doubts when handling cargo for BBC, should contact the BBC Port Captain department for guidance. It is of utmost importance to have an open dialogue and find solutions.

1. Lifting standards

1.1 Lifting equipment

Ships chartered by BBC Chartering have a certain assortment of lifting equipment on board. If the nature of cargo requires different equipment than already on board, same will be supplied by BBC Chartering.

In new ships under the charter of BBC Chartering, a standard equipment is carried, which will satisfy all expected employments of the vessel.

1.1.1 Wire rope slings and grommets

Vessels carry wire rope slings, wire rope grommets and wire belt slings. Wire rope slings are used for moving tween deck pontoons and other equipment only. For lifting cargo units, generally the grommets and belt slings are used.

The inventory list contains the operational parameters:

WLL = working load limit; WL = working length; wire rope diameter.

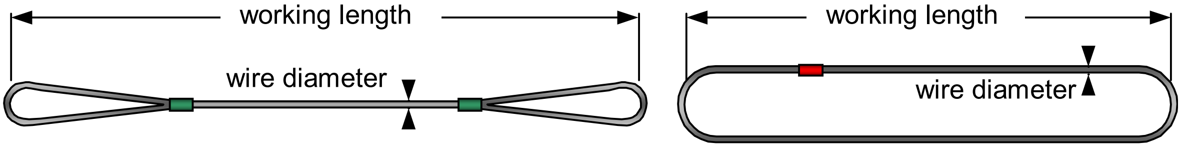


Figure 1.1: Wire rope slings (left) and wire rope grommets (right)

Slings and grommets should be kept gently greased for avoiding corrosion and returned to a sheltered storage location immediately after use.

1.1.2 Fibre rope grommets

Vessels carry endless belt slings of synthetic fibre material. Operational parameters are:

WLL = working load limit; WL = working length.

Fibre rope grommets should be protected from chafing damage and returned to the designated storage location immediately after use.

1.1.3 Shackles

Vessels carry lifting shackles of high tensile steel. Operational parameters are:

WLL = working load limit; A = inside width; E = inside length; D = bolt diameter.

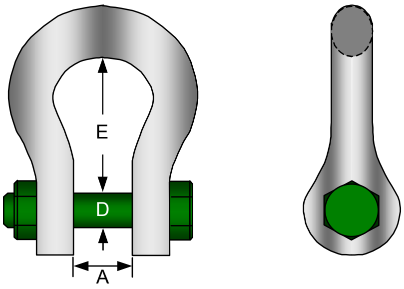


Figure 1.2: Green pin lifting shackles

1.1.4 Spreaders and beams

Vessels carry heavy load lifting beams and spreader beams. Operational parameters are:

SWL = safe working load; WL = working length (variable).

On some ships, two heavy load lifting beams may be coupled in parallel for acting as a connecting beam, if a short heavy unit shall be lifted with two cranes.

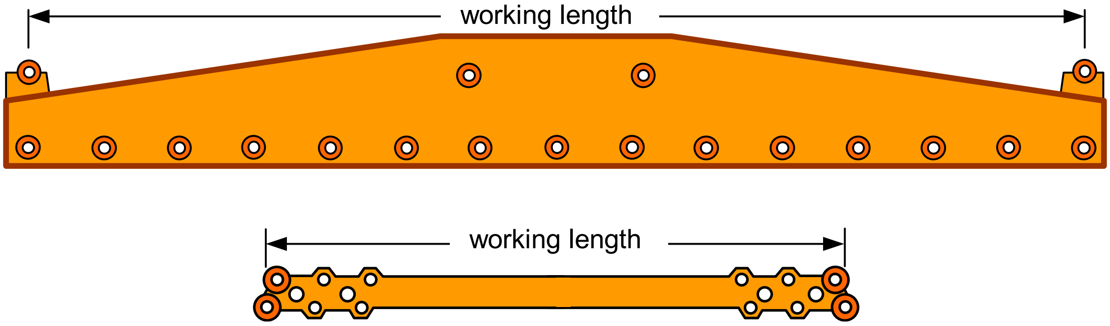


Figure 1.3: Heavy load lifting beam (top) and ordinary lifting beam (bottom)

1.1.5 Safety factors

All items of the lifting equipment are delivered and kept on board vessels together with appropriate certificates, issued by the manufacturer according to accepted standards. These certificates contain figures on the nominal breaking load BL and the working load limit WLL, both given in metric tons lifting capacity or in kN lifting force. The safety factor is the appropriate ratio of the figures:

$$\text{Safety factor} = \frac{\text{BL}}{\text{WLL}}$$

Safety factors range between 4 and 5 for wire rope material and are 7.1 for synthetic fibre material. The WLL-figures of the lifting equipment are crucial in the process of designing and approving a distinguished suspension arrangement.

1.2 Suspension arrangements

1.2.1 Single crane suspension without spreaders

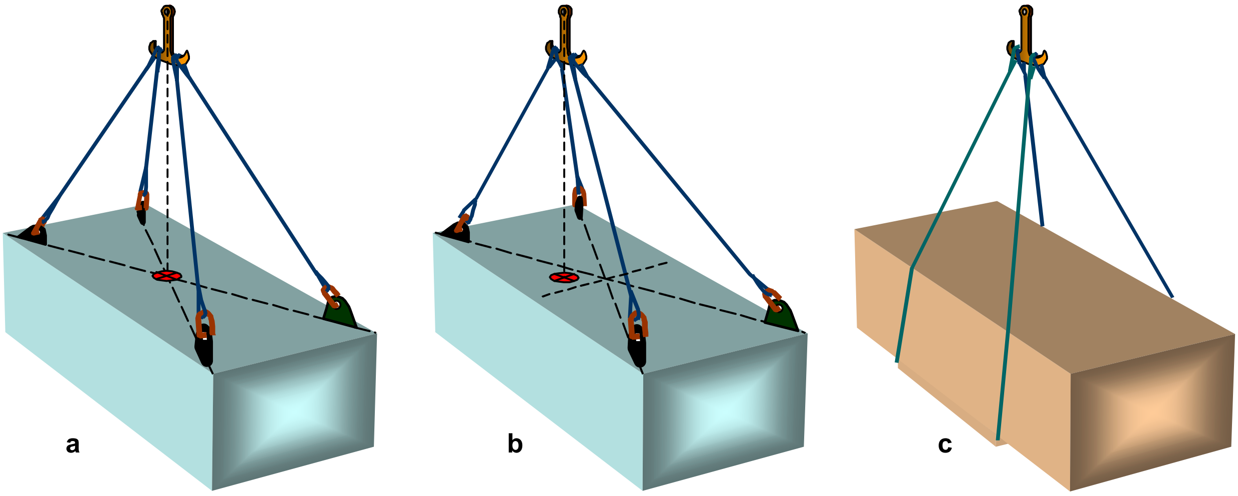


Figure 1.4: Single crane suspensions without spreaders

In any single crane suspension the centre of gravity of the cargo unit will inevitably hang vertically under the cargo hook. Therefore, the selection of slings may become critical with regard to the position of the centre of gravity and the endeavour to keep the hanging unit even.

The suspension in Figure 1.4.a with a centre of gravity in the geometrical centre of the lifting brackets requires four slings of identical length. Only then the four slings share the total load evenly. If only one sling is a little longer, it will be less loaded as well as the sling at the diagonally opposite side. The two other slings will have to share the balance and may be considerably overloaded.

The suspension in Figure 1.4.b with a centre of gravity off the geometrical centre of the lifting brackets requires four slings of carefully adapted length. The individual length of each sling must be determined by an appropriate drawing with due account for the geometry of the cargo hook and the effective length of shackles and brackets (see chapter 1.2.5).

The popular suspension method in Figure 1.4.c will conveniently equalise differences in length of the four vertical parts of the two slings. Any minor offset of the centre of gravity of the cargo unit can be compensated by shifting the slings about the bottom of the unit.

1.2.2 Single crane suspension with spreaders

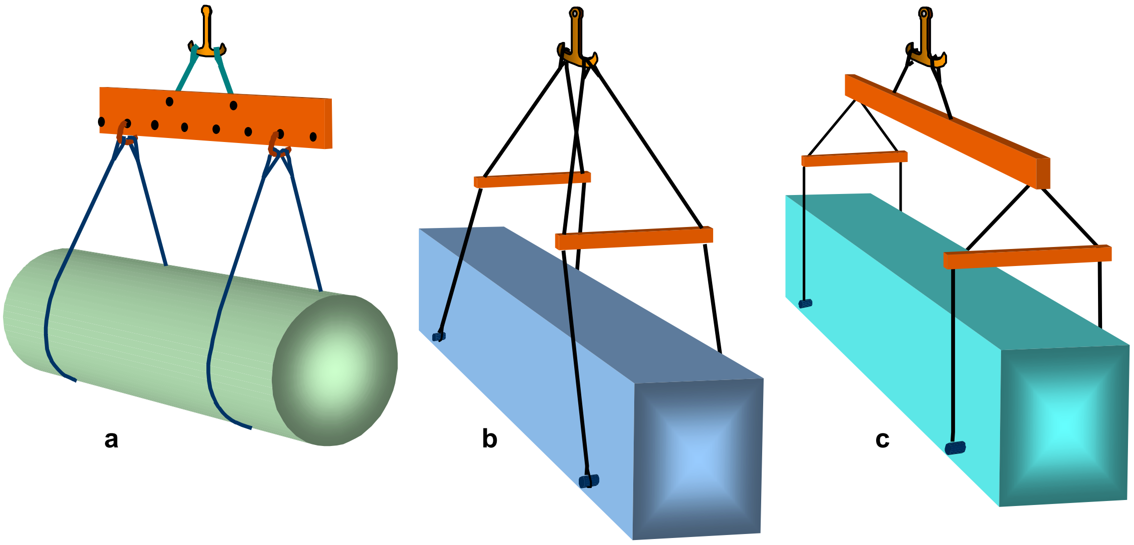


Figure 1.5: Single crane suspensions with spreaders

The cargo unit in Figure 1.5.a does not allow slings running inclined to the middle of the unit in order to avoid slipping. Therefore a longitudinal spreader or beam is required.

The suspension in Figure 1.5.b is required whenever slings touching the sides of the cargo unit shall be avoided. Therefore transverse spreaders are used. It should be noted, that this type of suspension is susceptible to transverse instability (see chapter 1.2.6).

The suspension in Figure 1.5.c is designed to avoid the slings touching the sides of the cargo unit and to keeping the slings vertical. Therefore transverse spreaders and a longitudinal beam are used. It should be noted, that this type of suspension is susceptible to transverse and longitudinal instability (see chapter 1.2.6).

1.2.3 Dual crane suspension with connecting beam

A cargo unit with a mass exceeding the lifting capacity of one crane alone must be lifted by two cranes. If the longitudinal distance of the lifting points on the cargo unit is short, there is a risk of collision of the crane jibs. In this case a connecting beam must be used. The connecting beam might also be used to equalise the weight to the cranes where the cargo unit has an off-centre c.o.g. or to bring the cargo unit into a stowage position that would not be reached without a beam.

In a dual crane suspension the centre of gravity of the cargo unit will always be between the two suspension points, preferably in the middle. Any offset from the middle causes uneven loads in the lifting tackles of the cranes.

Furthermore, dual crane suspensions always bear the risk of non-vertical hoist of the lifting tackles, which must be absolutely avoided.

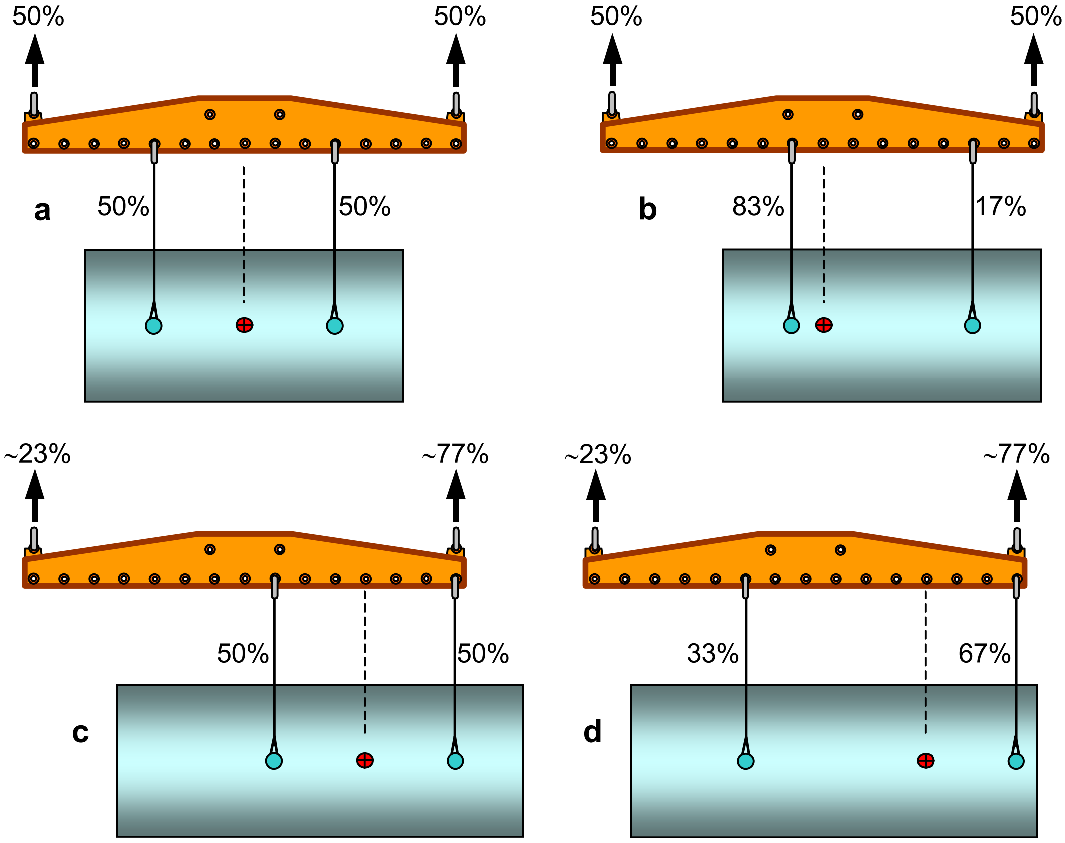


Figure 1.6: Dual crane suspensions with connecting beam

The suspension in Figure 1.6.a shows a symmetrical situation, where both cranes share the load evenly. This is also the case in Figure 1.6.b, because the offset of the centre of gravity is compensated in a way that it remains under the middle of the connecting beam. However the slings have to carry uneven loads (calculated example see chapter 1.2.7).

The suspension in Figure 1.6.c is asymmetric for the two cranes, possibly to reach a more remote stowage place in the ship. The suspension in Figure 1.6.d is asymmetric for the two cranes and also for the slings (calculated example see chapter 1.2.7).

1.2.4 Dual crane suspension without connecting beam

If the cargo unit is long with lifting points or slinging areas placed sufficiently apart, a connecting beam is not necessary in general. This increases the lifting capacity by saving the weight of the connecting beam.

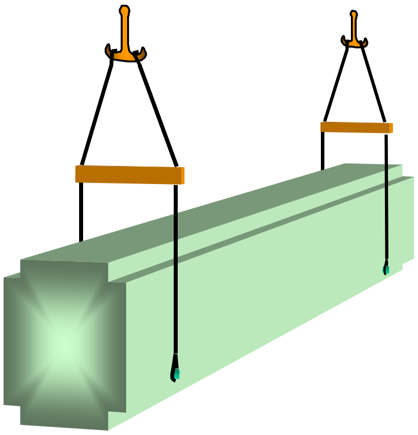


Figure 1.7: Dual crane suspensions without connecting beam

The suspension in Figure 1.7 is similar to the one in Figure 1.5.b, but shows vertical slings as in 1.5.c without the extra weight of a longitudinal beam. This type of suspension is susceptible to transverse instability (see chapter 1.2.6).

1.2.5 Determination of sling length

The vertical dimension of a suspension arrangement is the slinging height. It may become critical as it must never exceed the available hoisting distance.

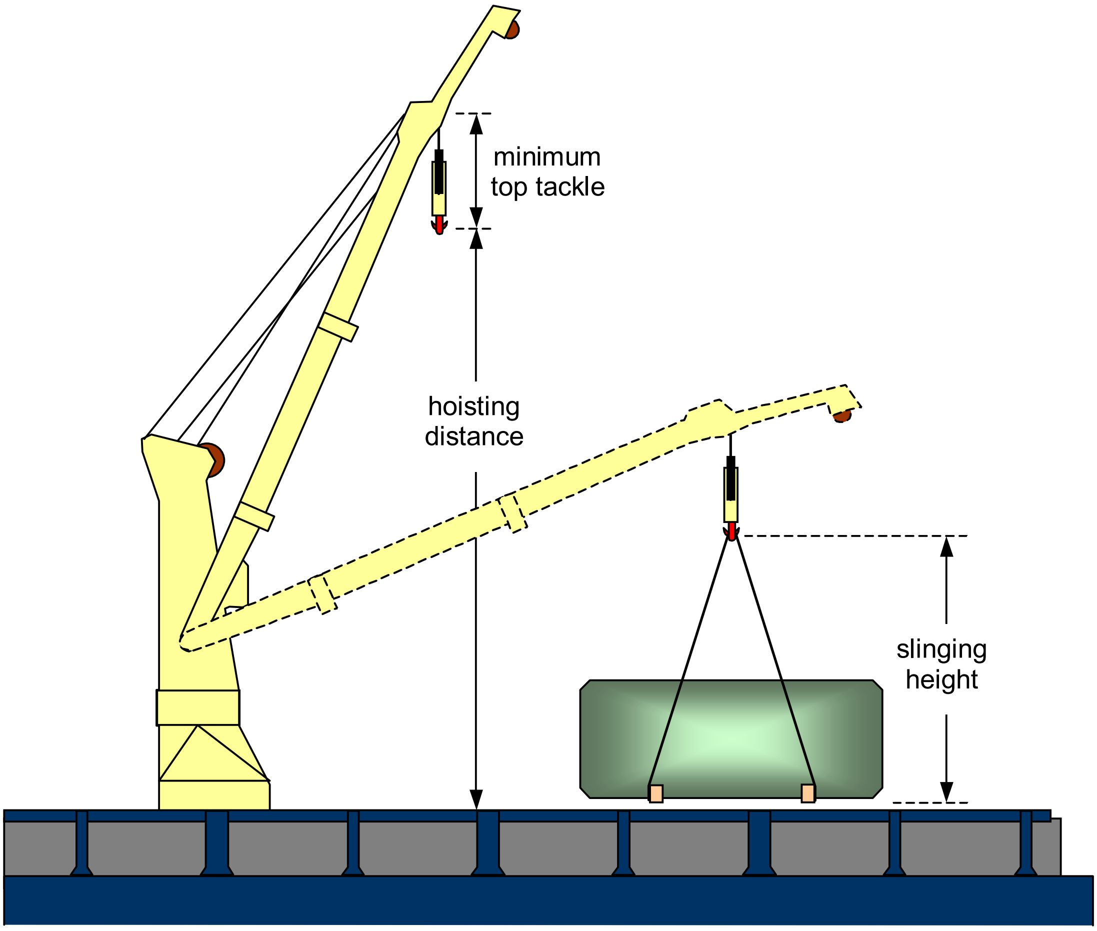


Figure 1.8: Hoisting distance and slinging height

The hoisting distance is the vertical distance from the top of weather deck hatch covers to the uppermost position of the crane hook. This distance is generally not critical for very heavy units, because then the working radius of the crane must remain small. However, it should be checked against the slinging height, if a not so heavy unit is intended to be stowed at a larger working radius where the hoisting distance may become small.

The slinging height is the vertical distance from the bottom of a cargo unit to the crane hook. It depends on the length of employed slings and spreader combinations in the suspension arrangement. The layout of a suspension arrangement must account for tolerable forces in the gear (chapter 1.2.7), for stability in the arrangement (chapter 1.2.6) and for the lifting facilities of the cargo unit in general.

In cases where the slinging height is the limiting criterion, the appropriate length of slings must be determined accordingly. This may be of particular importance if the centre of gravity of the cargo unit is out of the geometrical centre of the lifting points and sling lengths must be adapted individually.

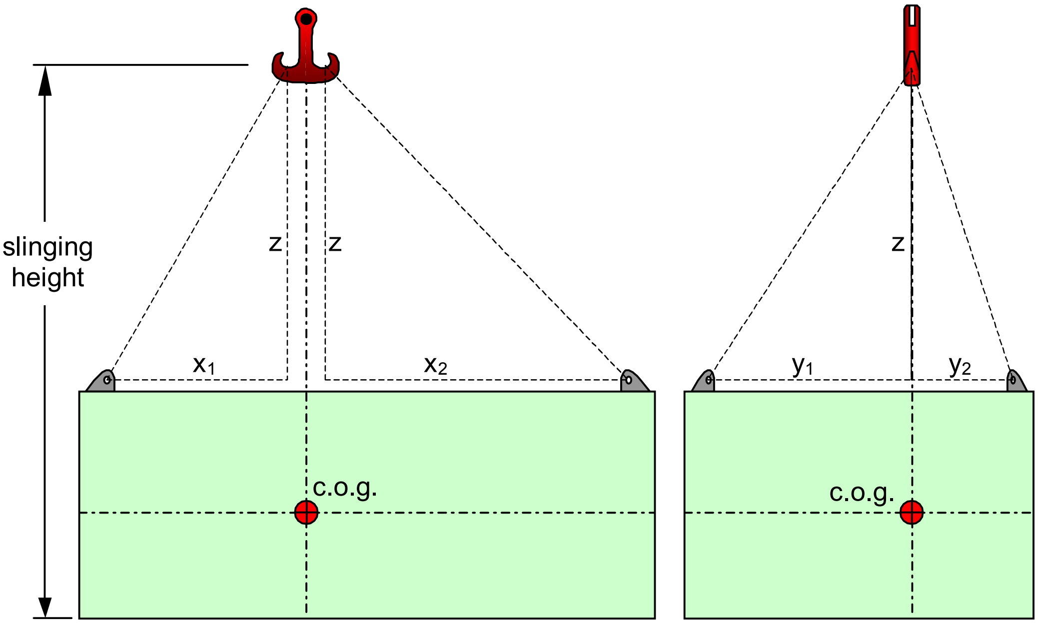


Figure 1.9: Determination of individual sling lengths from a scale drawing

The net length of each sling should be calculated using the cubical theorem of Pythagoras for the gross length and reducing the gross length by the effective length (E+D/2) of the shackle (see Figure 1.2). The figures of x, y and z must be obtained from a scale drawing or calculated, whatever is most appropriate.

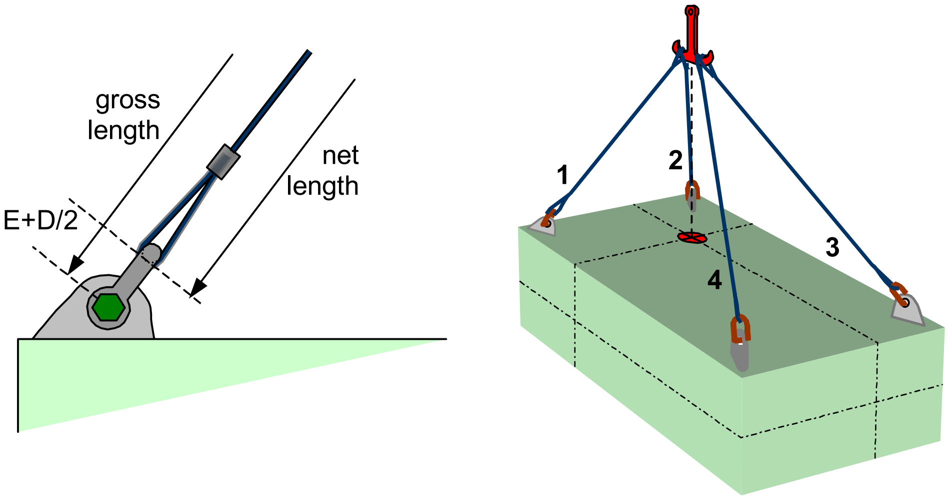


Figure 1.10: Calculation of gross and net length

$$\text{Net sling length 1} = \sqrt{z^2 + x_1{}^2 + y_1{}^2} - (E + D/2)\ \text{[m]}$$

$$\text{Net sling length 2} = \sqrt{z^2 + x_1{}^2 + y_2{}^2} - (E + D/2)\ \text{[m]}$$

$$\text{Net sling length 3} = \sqrt{z^2 + x_2{}^2 + y_2{}^2} - (E + D/2)\ \text{[m]}$$

$$\text{Net sling length 4} = \sqrt{z^2 + x_2{}^2 + y_1{}^2} - (E + D/2)\ \text{[m]}$$

Calculated example: $z = 8.2$ m; $x_1 = 4.7$ m; $x_2 = 7.9$ m; $y_1 = 5.3$ m; $y_2 = 2.6$ m; four shackles of WLL = 85 t with E = 330 mm and D = 85 mm.

$$\text{Net sling length 1} = \sqrt{67.24 + 22.09 + 28.09} - 0.37 = 10.47\ \text{m}$$

$$\text{Net sling length 2} = \sqrt{67.24 + 22.09 + 6.76} - 0.37 = 9.43\ \text{m}$$

$$\text{Net sling length 3} = \sqrt{67.24 + 62.41 + 6.76} - 0.37 = 11.31\ \text{m}$$

$$\text{Net sling length 4} = \sqrt{67.24 + 62.41 + 28.09} - 0.37 = 12.19\ \text{m}$$

1.2.6 Stability of suspension arrangements

The stability of a suspension arrangement behaves in analogy to the stability of a ship. In a ship, the centre of gravity (c.o.g) must always remain below the metacentre, which is the intersection of all buoyancy vectors at small angles of heel and may be looked at as a static centre of suspension of the ship.

A suspension, where the cargo unit is directly connected to the hook(s) by slings, may be called a primary suspension. Such arrangements are definitely stable, if the fastening points at the cargo unit are above its c.o.g. If the unit is fastened below its c.o.g., the arrangement is still stable, as long as the c.o.g. is kept below the centre of suspension (c.o.s.).

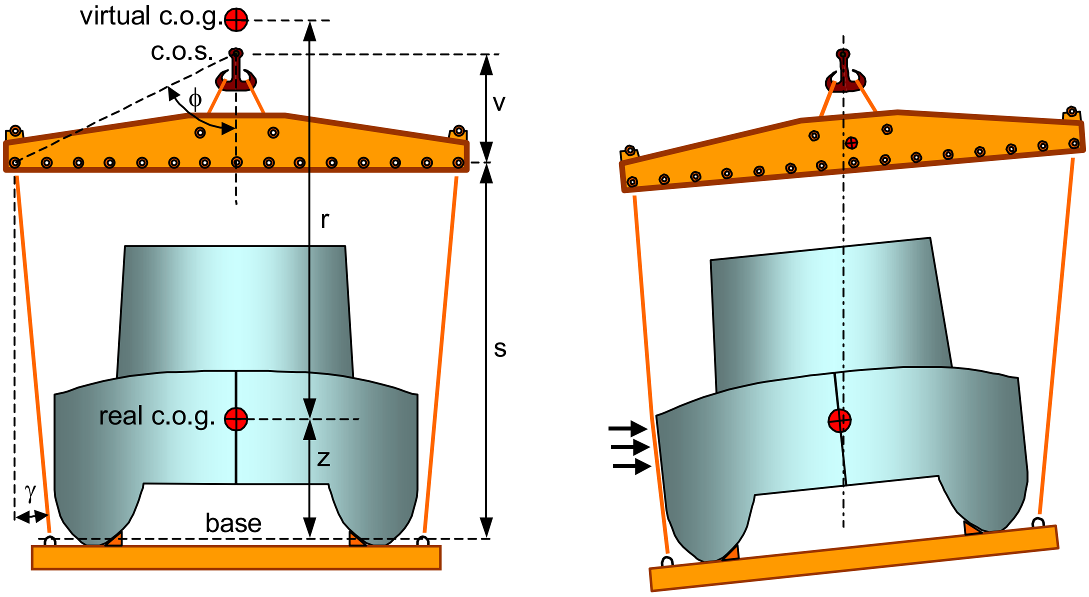


Figure 1.11: Unstable complex suspension arrangement, only stabilised by contact to slings

In a complex suspension arrangement, which includes spreaders or traverses hanging on a primary suspension, the cargo unit hangs on a secondary suspension. If there is a small horizontal offset of the centre of gravity in the cargo unit, the initial small tilting angle of the whole suspension will be amplified by the additional tilting of the secondary suspension. This effect is similar to the influence of liquid free surfaces in a ship and may in the same way be understood and quantified by raising the centre of gravity to a virtual position. The vertical distance r between the real c.o.g. and the virtual c.o.g. is given by the formula:

$$r = c \cdot s - v \cdot \frac{m_T}{m_C} - c \cdot z \cdot \frac{s \cdot \tan\gamma}{v \cdot \tan\varphi + s \cdot \tan\gamma} \ \text{[m]}$$

$$\text{with: } c = \cos^2\gamma - \left(1 + \frac{m_T}{m_C}\right) \cdot \frac{\sin\gamma \cdot \cos\gamma}{\tan\varphi}$$

- r = vertical distance between real c.o.g and virtual c.o.g. [m]
- v = vertical distance between spreader and centre of suspension [m]
- s = vertical distance between fastening points on cargo unit and spreader [m]
- z = vertical distance between fastening points on cargo unit and real c.o.g. [m]
- ϕ = primary suspension angle [°]
- γ = secondary suspension angle (negative for slings coming together at the base) [°]
- m_T = mass of spreader(s) [t]
- m_C = mass of cargo unit [t]

It should be noted that with a purely vertical secondary suspension with γ = 0 and c = 1, the above formula is simplified to read:

$$r = s - v \cdot \frac{m_T}{m_C} \ \text{[m]}$$

Ignoring the lessening term $v \cdot m_T / m_C$ in the sense of a safety margin renders r = s. That means, the c.o.g. is lifted to a virtual position by the approximate distance s. This distance becomes greater with negative angles γ and smaller with positive angles γ.

The unstable suspension arrangement in Figure 1.11 will not necessarily cause an accident, because the cargo unit is stabilised by contact to the slings. However, if there is a situation where the unit may tilt over unimpeded, extra care must be taken to provide a stable suspension.

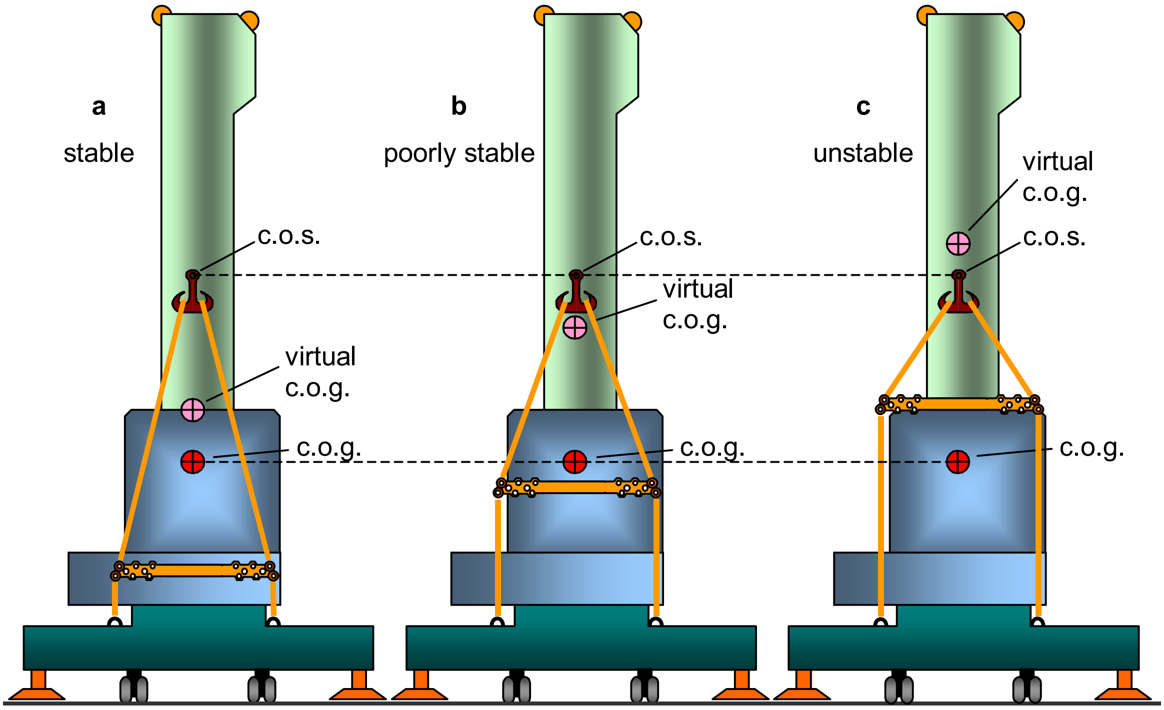


Figure 1.12: Stability under variation of primary and secondary suspension

Figure 1.12 shows three options of a lifting operation with identical positions of the centre of gravity (c.o.g) and the centre of suspension (c.o.s). The variation of the lengths of the primary and the secondary suspension results in different positions of the virtual centre of gravity. Option 1.12.a is stable, option 1.12.b is poorly stable and option 1.12.c is unstable.

For avoiding unstable suspension arrangements, the following recommendations should be followed:

- Make the height v of the primary suspension as long as possible.
- Make the height s of the secondary suspension as short as possible.
- Avoid negative suspension angles γ, i.e. secondary slings narrowing at the base.
- If in doubt, make a calculation and give a margin of at least 1 metre for the position of the virtual c.o.g below the c.o.s. Give a greater margin, if the position of c.o.g. is doubtful.

Calculated example: The lifting arrangement in Figure 1.11 shows the following parameters: v = 4.3 m; s = 14.9 m; z = 4.7 m; $\phi = 63°$; $\gamma = -6°$; $m_T = 40$ t; $m_C = 164$ t.

$$c = \cos^2(-6°) - \left(1 + \frac{40}{164}\right) \cdot \frac{\sin(-6°)\cdot\cos(-6°)}{\tan 63°} = 0.9945 + 1.2439 \cdot 0.0530 = 1.06$$

$$r = 1.06 \cdot 14.9 - 4.3 \cdot \frac{40}{164} - 1.06 \cdot 4.7 \cdot \frac{14.9 \cdot \tan(-6°)}{4.3 \cdot \tan 63° + 14.9 \cdot \tan(-6°)} \quad \text{m}$$

$$r = 15.794 - 1.049 + 1.06 \cdot 4.7 \cdot 0.2278 = 15.87 \quad \text{m}$$

In this example the centre of suspension is situated at a distance of s + v = 19.2 m above the base, while the virtual centre of gravity is situated at a distance of z + r = 20.6 m above the base. That indicates an unstable suspension.

1.2.7 Forces in lifting gear

Forces in a planned suspension arrangement must be checked in order to ascertain that no single item of the lifting gear will be loaded beyond its certified SWL or WLL. The required WLL-figures in a suspension arrangement should be determined in two steps:

- Determination of the vertical hanging forces,
- Calculation of effective forces in shackles and slings.

In case of a symmetrical suspension arrangement the hanging forces may simply be obtained by dividing the weight of the unit by the number of slings. In asymmetrical arrangements the hanging forces must be calculated. Suspension arrangements are statically determinate only, if there are one, two or three single suspensions.

A **two-point suspension** is calculated by using the principle of inverse proportionality.

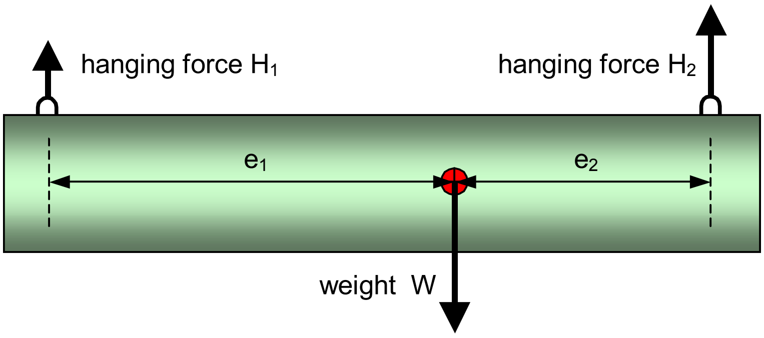


Figure 1.13: Principle of inverse proportionality

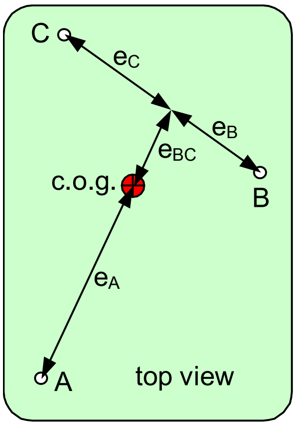
Figure 1.13 shows the principle of inverse proportionality, where the hanging forces are "inverse proportional" to their distance to the centre of gravity.

$$H_1 = W \cdot \frac{e_2}{e_1 + e_2} \quad [\text{kN}] \quad \text{and} \quad H_2 = W \cdot \frac{e_1}{e_1 + e_2} \quad [\text{kN}]$$

Calculated example: Mass = 125 t; weight = m · g = 125 · 9.81 = 1226.3 kN; $e_1 = 8.4$ m; $e_2 = 5.2$ m

$$H_1 = 1226.3 \cdot \frac{5.2}{8.4 + 5.2} = 468.9 \quad \text{kN} \qquad \text{and} \qquad H_2 = 1226.3 \cdot \frac{8.4}{8.4 + 5.2} = 757.4 \quad \text{kN}$$

In a **three point suspension** the hanging forces may also be accurately determined in the way shown below.



$$H_A = W \cdot \frac{e_{BC}}{e_A + e_{BC}} \quad [\text{kN}]$$

$$H_B = W \cdot \frac{e_A}{e_A + e_{BC}} \cdot \frac{e_C}{e_B + e_C} \quad [\text{kN}]$$

$$H_C = W \cdot \frac{e_A}{e_A + e_{BC}} \cdot \frac{e_B}{e_B + e_C} \quad [\text{kN}]$$

(W = weight of the unit)

Figure 1.14: Three-point suspension

Calculated example: e_A = 5.7 m; e_B = 2.9 m; e_C = 3.5 m; e_{BC} = 2.2 m; W = 981 kN

$$H_A = 981 \cdot \frac{2.2}{5.7 + 2.2} = 273.2\,\text{kN}$$

$$H_B = 981 \cdot \frac{5.7}{5.7 + 2.2} \cdot \frac{3.5}{2.9 + 3.5} = 387.1\,\text{kN}$$

$$H_C = 981 \cdot \frac{5.7}{5.7 + 2.2} \cdot \frac{2.9}{2.9 + 3.5} = 320.7\,\text{kN}$$

A **four point suspension** may only be approximated with sufficient accuracy, by breaking it down into a system of two-point suspensions. In Figure 1.15, the longitudinal distances x_i + e/2 and the transverse distances y_i of the lifting points from the centre of gravity are used for calculating the hanging forces. The appropriate formulas read:

$$H_1 = W \cdot \frac{x_2 + e/2}{x_1 + x_2 + e} \cdot \frac{y_2}{y_1 + y_2} \quad [\text{kN}]$$

$$H_2 = W \cdot \frac{x_2 + e/2}{x_1 + x_2 + e} \cdot \frac{y_1}{y_1 + y_2} \quad [\text{kN}]$$

$$H_3 = W \cdot \frac{x_1 + e/2}{x_1 + x_2 + e} \cdot \frac{y_2}{y_1 + y_2} \quad [\text{kN}]$$

$$H_4 = W \cdot \frac{x_1 + e/2}{x_1 + x_2 + e} \cdot \frac{y_1}{y_1 + y_2} \quad [\text{kN}]$$

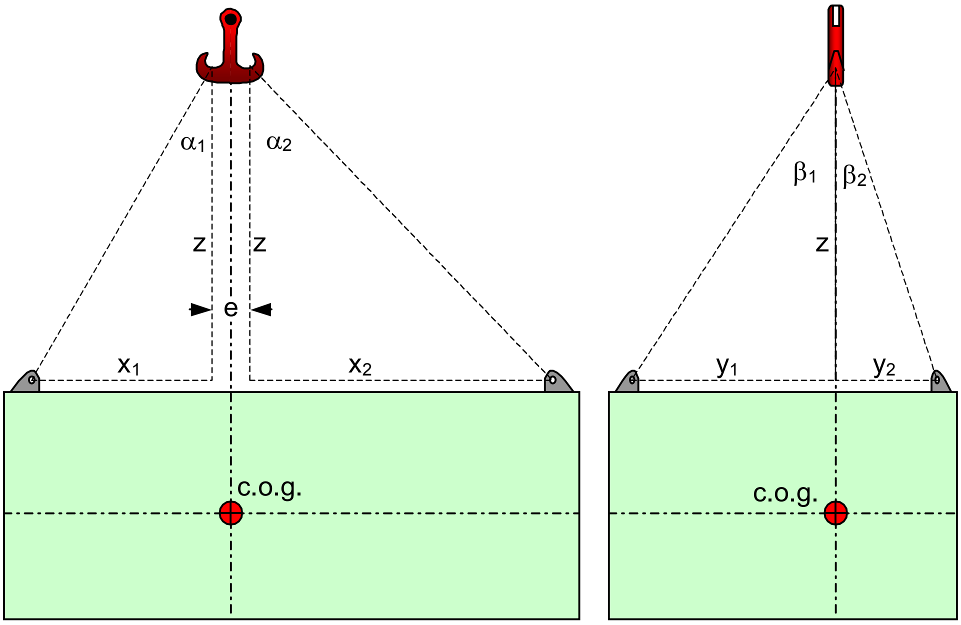


Figure 1.15: Approximation of hanging forces in a four-point suspension

The **effective forces** in shackles and slings depend on the suspension angle γ in a three-dimensional domain, as shown in Figure 2.16. These forces are calculated using the formula:

$$F = \frac{H}{\cos\gamma} \quad [kN]$$

The suspension angle γ should preferably remain below 30°, but should never exceed 60°. The values of suspension angles should be determined by appropriate scale drawings, together with the necessary length of slings.

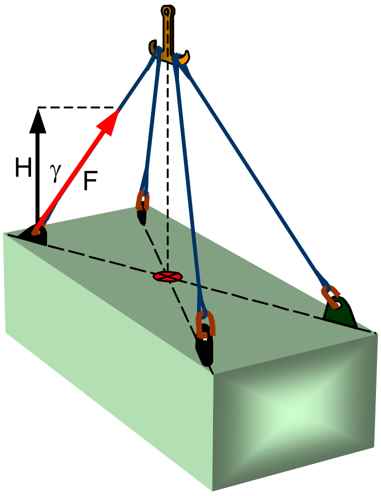


Figure 1.16: Effective forces in inclined suspension elements

The angle γ must be used in a spatial sense. If in a drawing (see Figure 1.15) the angles α and β are given in a side view and front view, the associated angle γ may be obtained by:

$$\tan\gamma = \sqrt{\tan^2\alpha + \tan^2\beta}$$

The effective force F is accordingly obtained by:

$$F = H \cdot \sqrt{\tan^2\alpha + \tan^2\beta + 1} \quad [kN]$$

A more simple approximation with an error on the safe side is:

$$F = \frac{H}{\cos\alpha \cdot \cos\beta} \quad [kN]$$

Calculated example: W = 120 · 9.81 = 1177.2 kN; e = 0.8 m; x_1 = 4.7 m; x_2 = 7.9 m; y_1 = 5.3 m; y_2 = 2.6 m; α_1 = 29.8°; α_2 = 43.9°; β_1 = 32.9°; β_2 = 17.6°.

$$H_1 = 1177.2 \cdot \frac{7.9 + 0.4}{4.7 + 7.9 + 0.8} \cdot \frac{2.6}{5.3 + 2.6} = 240.0 \text{ kN}$$

$$H_2 = 1177.2 \cdot \frac{7.9 + 0.4}{4.7 + 7.9 + 0.8} \cdot \frac{5.3}{5.3 + 2.6} = 489.2 \text{ kN}$$

$$H_3 = 1177.2 \cdot \frac{4.7 + 0.4}{4.7 + 7.9 + 0.8} \cdot \frac{5.3}{5.3 + 2.6} = 300.6 \text{ kN}$$

$$H_4 = 1177.2 \cdot \frac{4.7 + 0.4}{4.7 + 7.9 + 0.8} \cdot \frac{2.6}{5.3 + 2.6} = 147.4 \text{ kN}$$

Cross-check: $H_1 + H_2 + H_3 + H_4 = W$

Forces in slings:

$$F_1 = 240.0 \cdot \sqrt{\tan^2 29.8° + \tan^2 32.9° + 1} = 317.2 \text{ kN}$$

$$F_2 = 489.2 \cdot \sqrt{\tan^2 29.8° + \tan^2 17.6° + 1} = 584.7 \text{ kN}$$

$$F_3 = 300.6 \cdot \sqrt{\tan^2 43.9° + \tan^2 17.6° + 1} = 427.9 \text{ kN}$$

$$F_4 = 147.4 \cdot \sqrt{\tan^2 43.9° + \tan^2 32.9° + 1} = 225.7 \text{ kN}$$

Alternative approximate formula:

$$F_1 = \frac{240.0}{\cos 29.8° \cdot \cos 32.9°} = 329.4 \text{ kN}$$

$$F_2 = \frac{489.2}{\cos 29.8° \cdot \cos 17.6°} = 591.4 \text{ kN}$$

$$F_3 = \frac{300.6}{\cos 43.9° \cdot \cos 17.6°} = 437.7 \text{ kN}$$

$$F_4 = \frac{147.4}{\cos 43.9° \cdot \cos 32.9°} = 243.6 \text{ kN}$$

It is obvious, that the approximate formula provides a safety margin, which may be appropriate within the statically indeterminate four-point suspension.

1.2.8 Spreader support wires

Compression spreaders need support wires, which must not only carry the weight of the spreader but also a remarkable proportion of the weight of the cargo unit. Thus the total force in each support wire is:

$$F_S = \frac{H \cdot (1 - \cos\gamma o + W_S/2}{\cos\gamma} \text{ [kN]}$$

H = hanging force in sling [kN]
W_S = weight of compression spreader [kN]

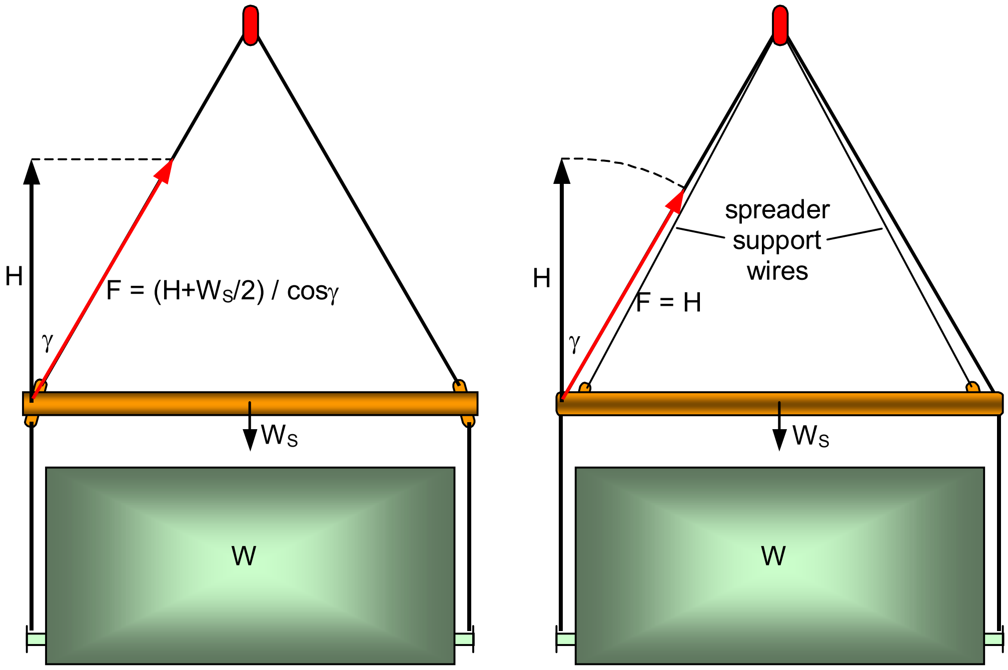


Figure 1.17: Spreader beam (left) and compression spreader (right)

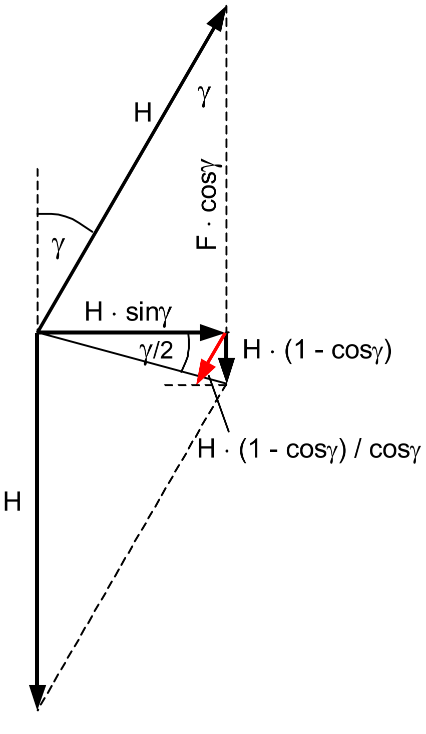


Figure 1.18: Cargo related force (red) in spreader support wire

Calculated example: A symmetrical dual crane suspension of a cargo unit of 244 t includes two transverse compression spreaders. The suspension angle γ is 40°. The mass of each spreader is 2 t. Each hanging force is:

$$H = \frac{244 \cdot 9.81}{4} = 598.4 \text{ kN}$$

The required WLL of each spreader support wire is:

$$F_S = \frac{598.4 \cdot (1 - \cos 40°) + 2 \cdot 9.81/2}{\cos 40°} = 192.8 \text{ kN}$$

Therefore the WLL of each spreader support wire should be about 200 kN or 20 t. The spreader support wires must be certified accordingly.

1.3 Ship's stability during lifting

1.3.1 Definitions and explanations

The following technical parameters are required for planning and controlling a heavy lift operation. They are also shown in Figures 1.20 and 1.24 below.

Constants for a particular ship:

B: Ship's moulded breadth.

q: Level of crane boom top (main hoist) in sea-condition above base. This figure may be obtained from the ship's capacity plan.

r: Level of lifting gear, mainly spreaders and traverses, in sea-condition above base. This figure may be obtained from the ship's capacity plan.

s_y: Transverse distance of centres of opposite anti-heeling tanks or other tanks suitable for counteracting any heeling during lifting operations.

Q: Heeling mass of crane boom(s), to be obtained from ship's documents or calculated as shown below, using crane manufacturer's information on mass and dimensions.

e: Effective length of crane boom from lower pivot to main hoist lifting tackle.

e_1: Distance of centre of gravity of crane boom to lower pivot.

f: Offset of lower pivot of crane boom to rotation centre of crane post.

m_b: Mass of crane boom.

Variables for each lifting operation:

P : Mass of the cargo unit to be lifted.

R: Mass of lifting gear (slings, spreaders, traverses).

S: Mass of ballast water to be transferred in the ship at the time of maximum heel. If one pair of opposite tanks is insufficient for compensating the heeling moment, two or more figures of "S" with appropriate figures of s_y and s_z must be used.

a: Required maximum outreach from the ship's railing during a lifting operation. The figure of "a" must be obtained in the process of pre-planning the lifting procedure.

p: Maximum required elevation of crane boom top (main hoist) above base. This figure may vary due to the planned lifting procedure and stowage location in the ship. In case of doubt, the maximum possible topping position should be used.

s_z: Vertical elevation of any ballast water transferred in the ship within the period of maximum heel.

d: Working radius of main hoist lifting tackle.

The lifting capacity of the crane is a function of its working radius d (see Figure 1.19), as shown in the crane manufacturer's documents and usually also programmed in the safety control system of the crane handling console. Therefore, when planning the lifting operation of a distinguished cargo unit, the mass of the unit P plus the mass of slings and spreaders R must be taken into account for the determination of the acceptable working radius d. This radius decides on the maximum outreach "a" from the ship's railing and also on the selection of the stowage place of the cargo unit in the vessel.

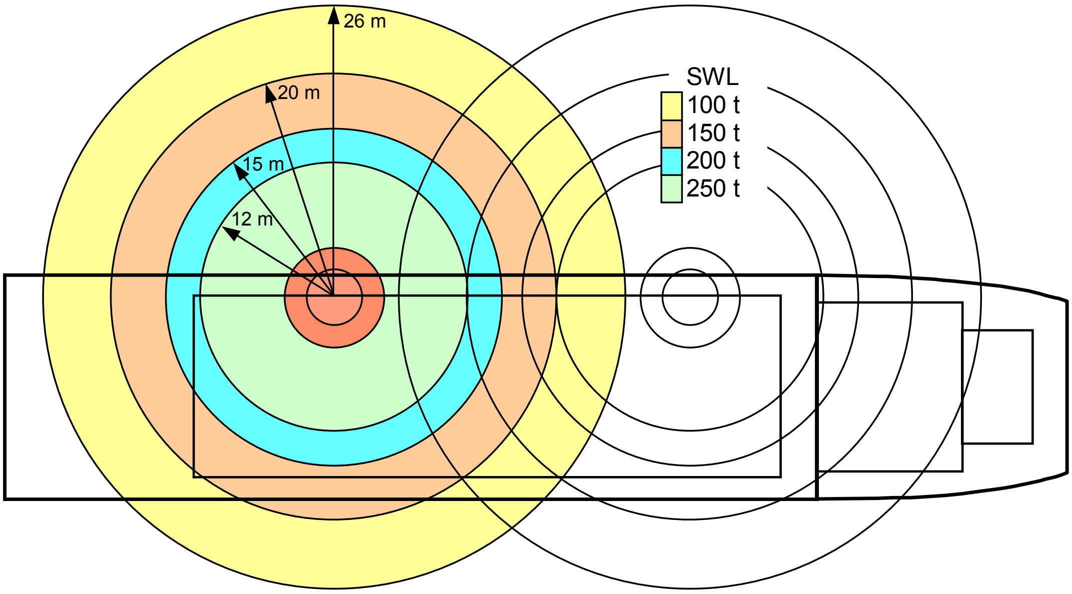


Figure 1.19: Diagram for range and SWL (Asia-class vessels)

As the permissible figures of SWL-capacity are generally given in steps of 50 t for associated working radii, it is appropriate to use linear interpolation for obtaining the working radius for any intermediate figure of SWL on all vessels with automatic mode on the cranes.

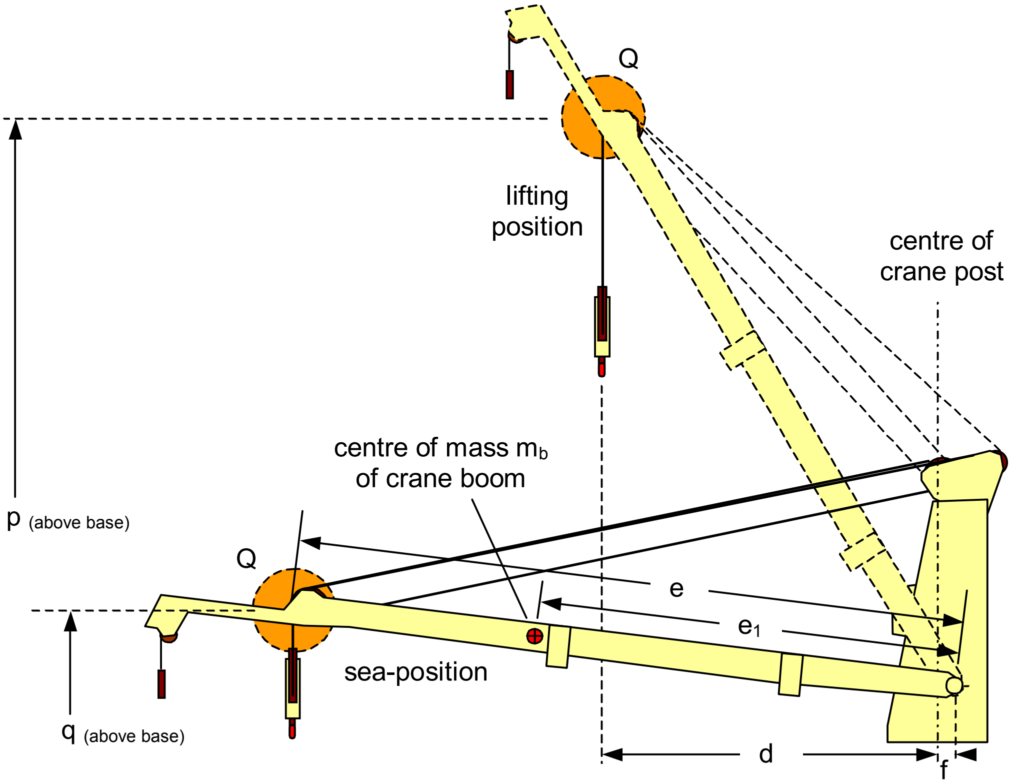


Figure 1.20: Parameters for lifting planning

During the preparation of a loading or unloading operation it may be necessary to simulate the turning in or turning out procedure, in order to evaluate the feasibility of complying with the SWL/radius relation as well as with any geometrical restrictions in case of large cargo units. This simulation may be carried out by means of a paper model of the cargo unit to scale with the ship's capacity plan or by using an appropriate computer program.

The ship's crane booms are included in the light ship mass of the vessel with their vertical centre of gravity in the sea-position. In the lifting position, the partial mass Q at the crane top is lifted up to the level of "p" metres above base and thereby reduces the stability of the vessel. The partial mass Q may be obtained from crane manufacturer's information on dimensions, mass and position of centre of gravity of the crane boom.

$$Q = \frac{m_b \cdot e_1}{e} \quad [t]$$

The level "q" of the partial mass Q in the sea-position above base may be taken from the ship's capacity plan. The figure of q is constant for a particular crane on a particular vessel.

1.3.2 Crane operations

A **single crane** lifting operation with maximum permissible SWL is characterised by the requirement that the crane hook must remain within the permissible working range at all times.

The possible outreach **a** from the ship's rail is therefore limited by the working range, reduced for the inboard position of the crane post. Apart from this restriction, the applicable figure of the outreach **a** will be governed by the size of the cargo unit and/or by the appointed distance to the vessel where it can be picked up or delivered (jetty, rail or barge).

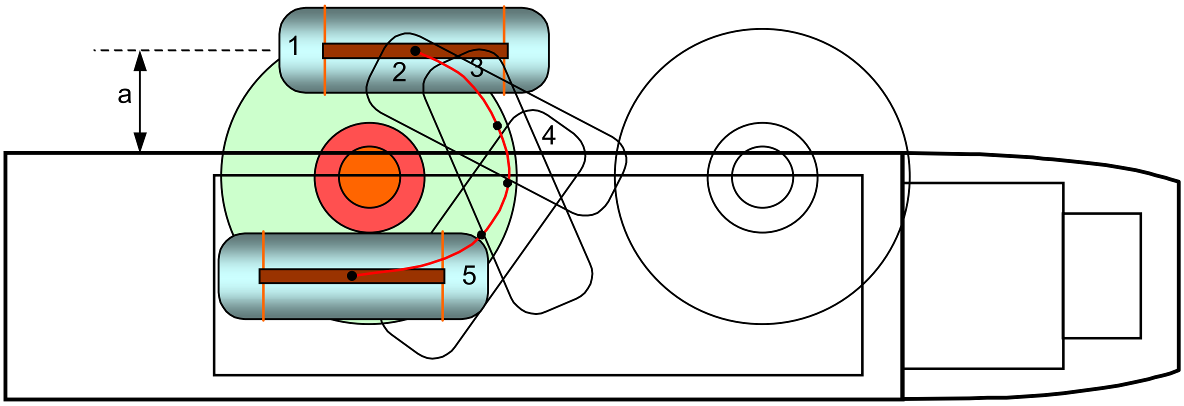


Figure 1.21: Single crane lifting operation

The maximum luffing angle, and therefore the maximum elevation **p** during the operation, depends on the planned stowage location. In the example in Figure 1.21 the maximum elevation has been reached in position (5), while in positions (1) to (4) the elevation is less.

A **dual crane** lifting operation with maximum permissible SWL and a cargo unit that is too short for direct access by each hook must be lifted by means of a **connecting beam**. Also this procedure is characterised by the requirement that both hooks must remain within the permissible working range at all times.

The possible outreach **a** from the ship's rail is therefore limited by a simple geometrical relation of the permissible working range to length of the beam, distance between crane posts and again reduced by the inboard position of the crane posts (see Figure 1.22).

The maximum luffing angle, and therefore the maximum elevation **p** during the operation, will appear exactly when the cargo unit passes between the crane posts. In the example in Figure 1.22 this is position (2).

Due care must be taken in a dual crane operation that both lifting tackles remain vertical at all times.

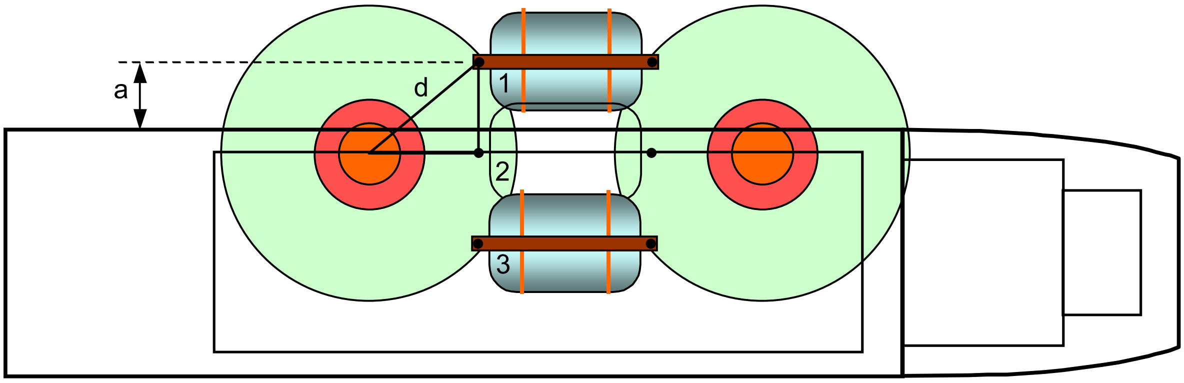


Figure 1.22: Dual crane lifting operation with connecting beam

A **dual crane** lifting operation with maximum permissible SWL and a cargo unit that is long enough for direct access by each hook, should be done **without connecting beam**. Also this procedure is characterised by the requirement that both hooks must remain within the permissible working range at all times.

The possible outreach **a** from the ship's rail is therefore limited by a similar geometrical relation of the permissible working range to distance of slinging points, distance between crane posts and again reduced by the inboard position of the crane posts (see Figure 1.23).

When the length of the cargo unit is greater than the free space between the crane posts, the unit must be moved between the cranes one end after the other. The maximum luffing angle, and therefore the maximum elevation **p** during the operation, will appear approximately when the cargo unit passes between the crane posts. In the example in Figure 1.23 this is position (4). However, it may be that the maximum elevation is greatest in the outboard position (1), depending on the pick-up or delivery distance **a**, or it is greatest in the position (6), depending on the stowage place on board.

Also without a connecting beam, due care must be taken that both lifting tackles remain vertical at all times.

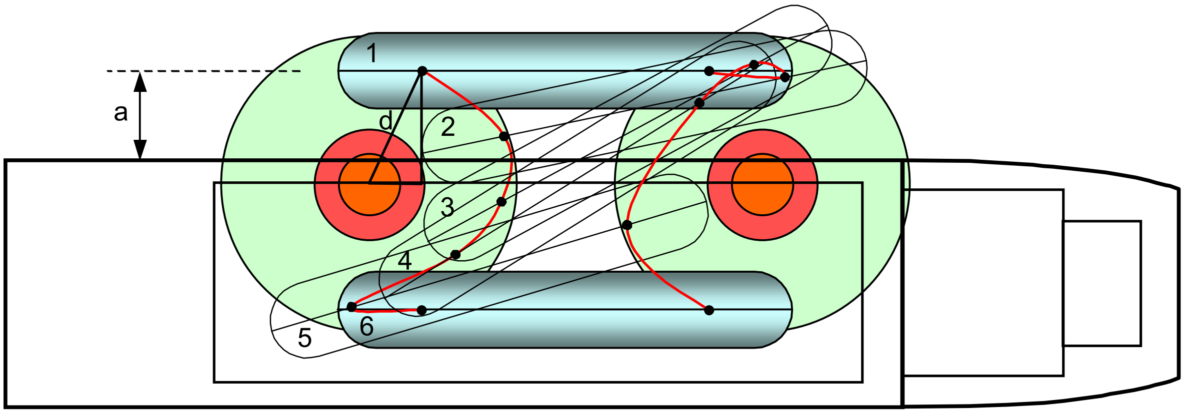


Figure 1.23: Dual crane lifting operation without connecting beam

1.3.3 *Verification of anti-heeling capacity and GM_C**

Prior to any lifting operation the stability of the vessel must be checked carefully under the responsibility of the master. This procedure includes the verification of sufficient anti-heeling ballast capacity. The parameters used in the assessment of the effective metacentric height GM_C* in the worst condition during lifting are shown in Figure 1.24.

The following steps of calculation are recommended:

1. The actual stability of the ship shall be calculated by means of the approved loading and stability computer with due compilation of all cargo on board, contents of ballast-, bunker-, freshwater- and

operational tanks, hatch covers and tween deck pontoons in actual position, and cranes in sea-position. Results are the displacement and KG_C (corrected for free surfaces).

2. Calculation of the required anti-heeling ballast capacity S.

$$S = \frac{(P+Q+R)\cdot(B/2+a)}{s_y} \quad [t]$$

3. Correction of displacement and KG_C for the worst condition during lifting. That is the highest topping position of the crane or cranes. The result is KG_C^* and GM_C^*.

$$KG_C^* = KG_C + \frac{P\cdot(p-KG_C)+Q\cdot(p-q)+R\cdot(p-r)+S\cdot s_z}{\text{displacement}+P} \quad [m]$$

$$GM_C^* = KM^* - KG_C^* \quad [m]$$

(KM* to be obtained for the lifting displacement in the actual trimmed condition)

The figure of GM_C* should be in the range of 1 metre but never less than 0.6 metres.

The stability assessment as described above shall be properly documented. The results shall be submitted to BBC Chartering.

Calculated example: The required ballast capacity S and GM_C* shall be calculated.

- Displacement = 8000 t; KG_C = 5.40 m; KM_{8000} = 9.10 m; KM_{8475} = 9.15 m
- P = 474 t; R = 26 t
- Q = 64.1 t; (Q_1 = 56.2 · 16.5 / 28.2 = 32.9 t; Q_2 = 53.3 · 16.5 / 28.2 = 31.2 t)
- p = 46.9 m; q = 23.2 m; r = 16.0 m (from crane documentation)
- B/2 = 10.1 m; a = 6.3 m; s_y = 18.2 m; s_z = 3.5 m

$$S = \frac{(474+26+64.1)\cdot(10.1+6.3)}{18.2} = 508\ t$$

At least 508 t of ballast water must be ready in the port side tank for transfer into the starboard side tank. The starboard side tank must be able to take this amount of ballast water.

$$KG_C^* = 5.40 + \frac{474\cdot(46.9-5.4)+64.1\cdot(46.9-23.2)+26\cdot(46.9-16.0)+508\cdot 3.5}{8000+474} = 8.21\,m$$

$$GM_C^* = 9.15 - 8.21 = 0.94\ m$$

This GM_C* is sufficient but not too abundant for the intended lifting operation.

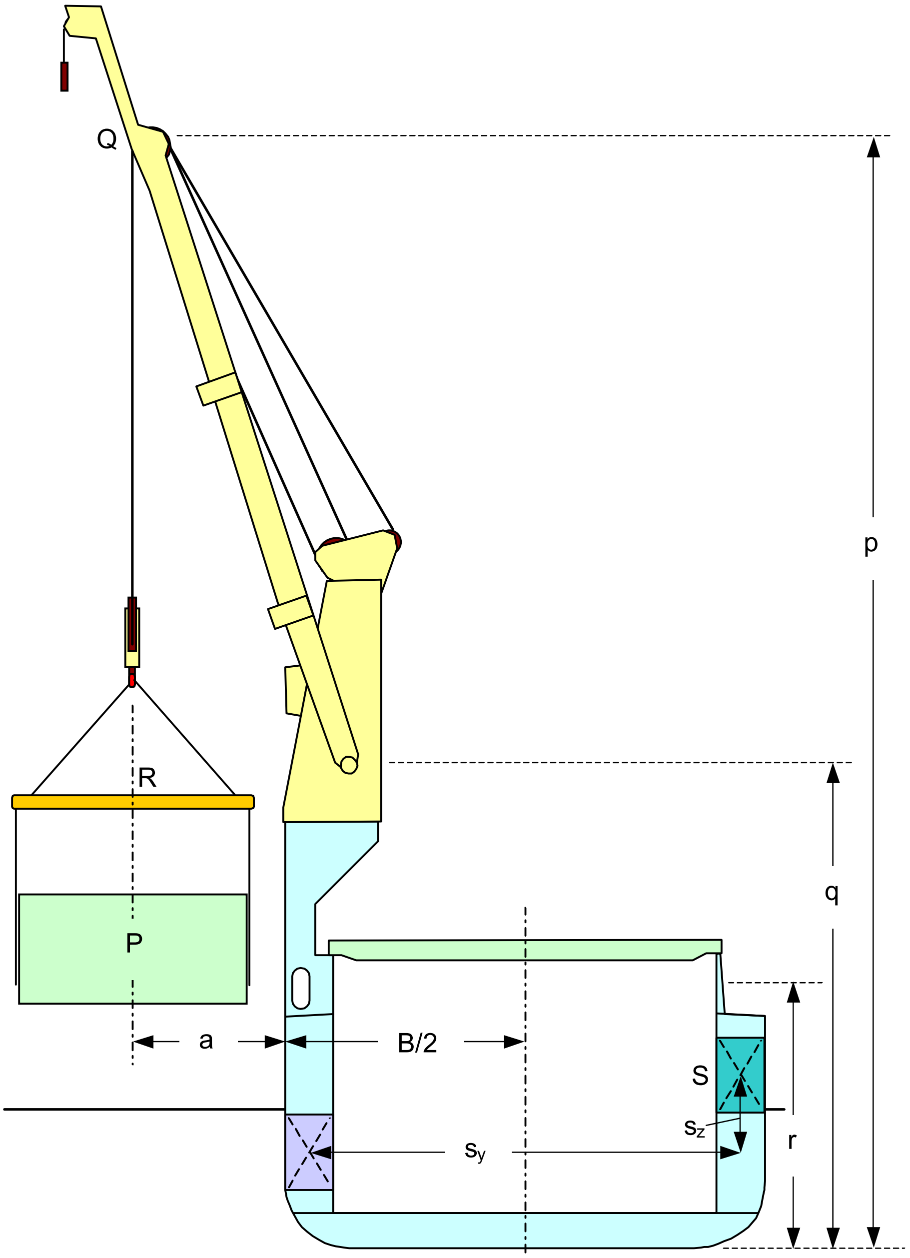


Figure 1.24: Stability parameters for lifting operations

1.3.4 Operation of stability pontoons

On vessels equipped with stability pontoon(s), these may be utilised for improving stability during lifting operations. In this case, the appropriate hydrostatic tables for activated pontoon(s) must be used in any stability consideration.

However, care must be taken never to overload the outriggers of these pontoons. It should be noted that the pontoons and their outriggers are merely dimensioned to provide additional initial stability to the vessel in a heeling range of maximum ± 3°. Therefore any heeling of the vessel appearing during lifting operations is restricted to **maximum 1°**, unless another figure is presented in the operation manual of the ship. If the limiting heeling angle is approached, the heel must be immediately reduced by the dedicated ballast tanks.

If the connection of the pontoon(s) to the vessel gives way due to overloading – either by lifting the pontoons too high or by submerging them too deep – the stability of the vessel will collapse with a subsequent immediate capsize of the ship. This is demonstrated by the righting lever curve in Figure 1.25.

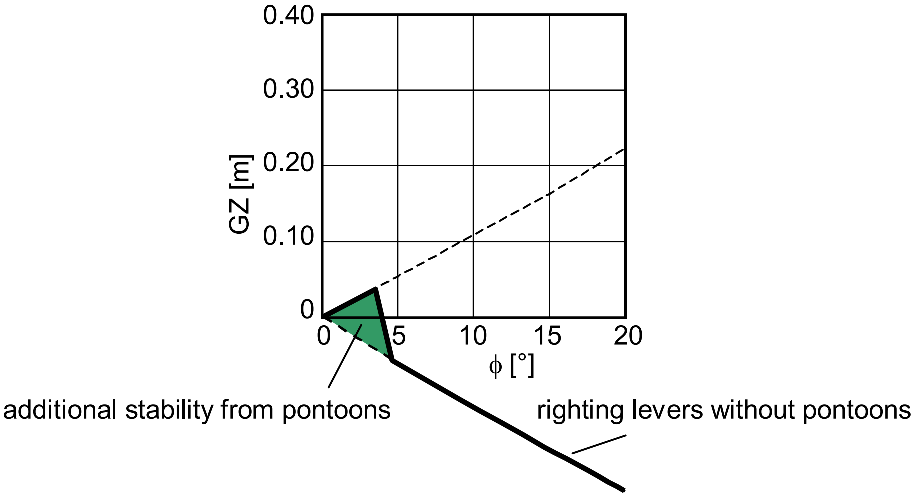


Figure 1.25: Ship lifting stability improvement using outrigger pontoons

The righting lever curve in Figure 1.25 shows a lifting situation with $GM_C^* = 0.63$ m obtained by the employment of stability pontoons. There is a dramatic decline in the curve if a heeling angle of 3° is exceeded and the pontoon outriggers begin to break down. After that, the green shaded part of the curve will have disappeared leaving the ship with a $GM_C^* = -0.70$ m with the hanging heavy lift unit.

1.4 Lifting procedure

1.4.1 General precautions

During lifting operations three different angles have to be observed:

The **heeling angle** ϕ of the ship shall at no time exceed ± 3° in a lifting operation without using stability pontoons. With stability pontoons engaged, the heeling angle shall never exceed ± 1°.

The **luffing angle** α of the crane boom shall remain above the lower limit referring to the actual load (P + R) = SWL at the hook. This may be automatically controlled in certain crane types.

The **hoisting angle** δ of the lifting tackle is normally equal to zero with a hanging cargo unit in a single crane operation. It may deviate from zero with a hanging cargo unit in a dual crane operation and shall be limited to 3° maximum at any time.

A hoisting angle other than zero may also appear in a single or dual crane operation during the period of lifting a unit from a barge or jetty or placing it down to a barge or jetty, while the ship heels due to the change of the hanging weight. This hoisting angle produces a risk of sliding of the cargo unit at its bedding on the barge or jetty, when the load at the lifting tackle exceeds a certain percentage of the actual mass of the cargo unit. This percentage depends on the hoisting angle as shown in the table, based on a friction coefficient of $\mu = 0.3$.

hoisting angle	1°	2°	3°
critical load %-age of actual cargo mass (see load indicator)	95 %	90 %	85 %

Therefore, whenever the cargo unit comes to rest with 20% or less of its weight on the barge or jetty and 80% of its weight or more taken by the hook(s), the hoisting angle must be kept to zero by means of the ship's heeling tanks and/or by operating the luffing gear of the crane(s).

Before a lifting procedure is started, all necessary actions must have been taken for improving and safeguarding the stability and the anti-heeling capacity of the ship. The following list of measures should be considered, but is not necessarily exhaustive.

- Take in ballast and bunkers as necessary.
- Avoid free liquid surfaces in ballast tanks by making an overflow at least two times before starting the lifting operation, and by taking soundings in tanks that should be empty. Do not rely on remote level indicators.
- If necessary/possible, shift tween deck pontoons into the lower hold at the starboard side.
- If necessary, transfer fuel oil to the starboard side and/or consume from port at the previous voyage, compensating the weight by ballast in the port side tanks.
- Fill heeling tanks on port and empty heeling tanks on starboard as necessary.
- Restrict the opening of weather deck hatch covers or shift pontoon type covers ashore.
- If necessary, lower both anchors with chains to the harbour ground.
- In case of single crane operation, lower the other crane to sea stowage position.
- Drain the swimming pool.
- Close all openings near the waterline (bull eyes, access ports) and take the gangway in.
- Keep the mooring lines tended (not too slack, not too tight).

Further precautions need to be taken as follows:

- The lifting checklist must be filled out according to the vessel's SMS-Manual.
- A pre-operation meeting must be held prior to cargo operations and all parties involved must be aware of the nature of the operation to be carried out. The lines of communication must be agreed and specific duties assigned. The sequence of operations must be explained and safety areas for visitors allocated.
- The lifting equipment, as compiled by BBC Chartering or by the vessel's command (slings, shackles, beams, spreaders), must be visually checked before assembly and the associated equipment certificates must be checked as well.
- The necessary ship's auxiliary power supply must be arranged and diesel day-tank(s) filled properly.
- The required action personnel and timed relief personnel, if necessary, must be appointed: Officer in charge, crane driver(s), pump operator, auxiliary personnel as necessary, engineer, person for overall surveillance of the vessel.
- Communication equipment must be charged in time and tested before use. Guide ropes should be prepared as necessary.
- In principle, lifting operations should be carried out during daylight only. Deviation from this rule should be agreed by BBC Chartering and accounted for by additional superintendence.
- A short de-briefing meeting should take place after completion with all personnel involved for reviewing and evaluating the performance of the lifting operation.

1.4.2 Personnel management

The officer in charge is in command of the crane driver(s), the pump operator and the auxiliary personnel. He/she has to advise and direct all activities with regard to preparation of the equipment and the actual handling of the cargo unit(s). He/she should have gained experience for these duties by assisting lifting operations and being in charge under supervision.

The crane drivers should be trained properly and be fully conversant with the technical equipment of the crane control cabin. They should be physically and mentally fit and knowledgeable of the crane driving commands.

The pump operator should be trained properly and be fully conversant with the technical equipment of the ballast pump control station. He/she should be physically and mentally fit and knowledgeable of the pump operation commands.

The assisting deck crew members should be physically and mentally fit for their duties.

The duty engineer should be physically and mentally fit and capable of controlling the required power supply.

The overall surveillance, in delicate situations preferably the master of the vessel, should among others have an eye at the "angles" mentioned above, on wind, swell, passing vessels and the mooring condition of the ship, and make records and take photographs as appropriate.

If a Port Captain is assigned to the loading venture, he is responsible for assisting the master, officers and crew with all planning and operational execution matters and to give officers and crew appropriate advice where required. The Port Captain shall further assist the vessel with documenting the operation and all paper work required.

1.4.3 Loading procedure

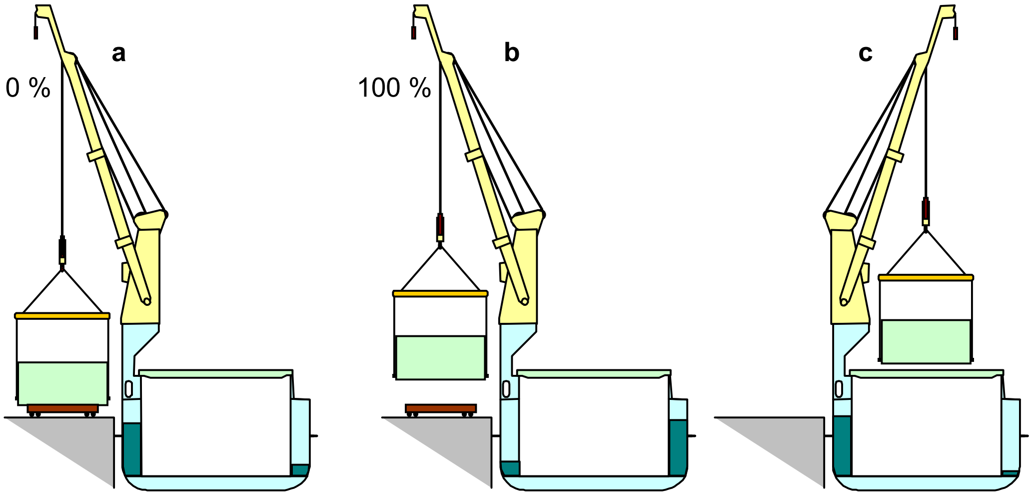


Figure 1.26: Loading procedure

Care should be taken that the cargo unit is brought alongside to a distance "a", that is not greater than anticipated and verified in the pre-planning calculation (see chapter 1.3.3).

After connecting the cargo unit to the lifting gear with a hoisting angle δ = 0° (Figure 1.26.a), start heaving the hoisting tackle to take a minor share of the load. Then stop hoisting and start pumping ballast to starboard and/or top up the luffing gear of the crane boom to reduce the hoisting angle to zero.

Any further hoisting must be done carefully hand in hand with keeping the hoisting angle close to zero by the ballast pump and/or the luffing gear, until the cargo unit is hanging freely (Figure 1.26.b), with the bulk of anti-heeling ballast at the starboard side.

Then start swinging the boom(s) to starboard in short steps, hand in hand with pumping ballast water back to the port side. This is completed when the cargo unit is hanging over the vessel ready to be lowered to the designated stowage position (Figure 1.26.c).

In a dual crane operation, care must be taken that during moving the cargo unit from out-board to the designated stowage position, the hoisting angles must remain close to zero at all times. Therefore turning the crane consoles should be never carried out simultaneously but one after the other with constantly checking the hoisting angles.

1.4.4 Unloading procedure

Care should be taken that the reception unit for the heavy lift is brought alongside to a distance "a", that is not greater than anticipated and verified in the pre-planning calculation (see chapter 1.3.3).

All lashings and vertical clamps at the cargo unit must be removed. Horizontal stoppers may remain in place with face plates removed to provide some freedom for initial lifting. Before lifting is started, care must be taken that the hoisting angle δ = 0°. After initial lifting a few centimetres with the cargo unit still kept between the stoppers, the hoisting angle may be adjusted further, in order to avoid damage to adjacent cargo units (Figure 1.27.a).

When the cargo unit has been lifted clear above the hatch coaming level, the boom(s) must be turned to port in short steps, hand in hand with pumping ballast water to the starboard side. This must be done in the same careful manner as described above for the loading procedure.

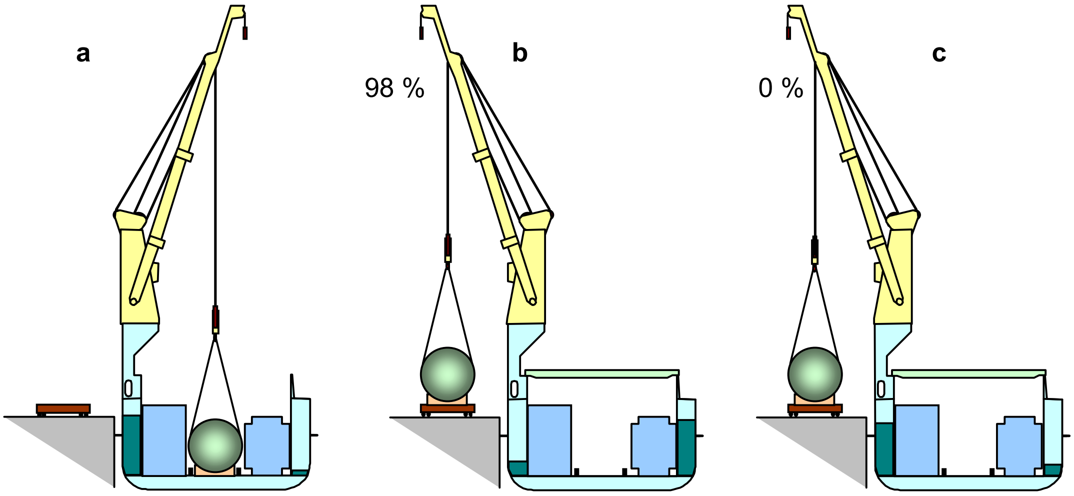


Figure 1.27: Unloading procedure

When the anticipated out-board position has been reached with the bulk of anti-heeling ballast at the starboard side, the cargo unit should be lowered to the reception vehicle or barge. After a slight touch down with about 2 to 5 t ease in the load, stop lowering further with the hoisting tackle and start to pump ballast back to the port side and/or lower the luffing gear of the crane boom(s) as appropriate, in order to keep the hoisting angle close to zero (Figure 1.27.b).

When the load in the lifting tackle has been reduced to less than 80% of the mass of the cargo unit, down to 0%, any further lowering may tolerate a hoisting angle up to 3°. However, care should be taken, if the vessel is exposed to slight swell in the harbour. In this case any hoisting angles during setting down the cargo unit should be avoided altogether (Figure 1.27.c).

2. Bedding Standards

2.1 General principles

Dry cargo ships are traditionally designed with sufficient strength for loading them down with a homogeneous cargo in all cargo spaces, or with a homogeneous cargo on the double bottom tank top alone, if strengthened for heavy cargoes on owners demand. For these loading assumptions figures of permissible area load (PAL) are defined for the double bottom tank top and the tween deck areas or pontoons.

The weather deck hatch covers have a minimum strength governed by class rules with regard to wave impact, but their actual strength may be increased on owner's demand for the stowage of deck cargo and is therefore also given a distinguished PAL.

If the ship is additionally dedicated for the carriage of standardised containers, the structural strength of tank top, tween deck and hatch covers must accommodate the agreed stack loads.

The figures of PAL and the permissible stack loads are documented in the ship's capacity plan and in the appropriate chartering specifications of the vessel.

2.1.1 Ship's structural capacities

Typical figures of PAL and container stack loads for ships operated by BBC Chartering are presented by those of the "Asia"-Type:

Lower hold tank top:	16.0 t/m^2
Tween deck pontoons hold 1:	2.5 t/m^2
Tween deck pontoons hold 2:	3.0 t/m^2
Weather deck hatch covers:	2.5 t/m^2

Lower hold 20'-containers:	100 t/stack
Lower hold 40'-containers:	120 t/stack
Weather deck 20'-containers:	60 t/stack
Weather deck 40'-containers:	80 t/stack

These figures must be observed in a qualified manner, when planning the bedding of heavy cargo units with limited foot print areas. It may be necessary to use suitable timber or steel beams for either simply spreading the given load onto a greater area or purposefully transferring the load onto the main girders of the hatch cover or tween deck pontoon.

2.1.2 Introduction to the beam theory

The beam theory is a fundamental element of engineering mechanics. It may be used as a tool for assessing distinguished load distributions within the planning of a project cargo shipment.

A beam is a lengthy piece of material, which in the most simple approach rests on its ends and is loaded in an arbitrary pattern from above. For such a situation, usually several questions must be answered:

1. Which shear forces and bending moments act on the beam due to that loading?
2. To which stresses is the beam exposed by these forces and moments?
3. Are these stresses permissible with regard to the strength of the beam material?

Figure 2.1 shows a beam of the length r that carries a symmetric load m or weight m·g over the distance s. The supporting forces at both ends of the beam are m·g/2, if the own weight of the beam is ignored.

The left supporting force is the immediate shear force at the left end of the beam. This shear force remains until it is steadily reduced along the beam by the counteracting weight of the payload with an equilibrium at half the length and a final surplus of weight to the right end. This surplus is finally compensated by the other supporting force m·g/2 at the right end.

The bending moments along the beam are found by a step by step integration of the area under the shear force curve. The greatest bending moment BM_{max} is therefore equal to the area under the shear force curve up to its zero. This BM_{max} is generally the deciding parameter for defining the necessary strength of the beam. For obtaining this area in arbitrary and asymmetric load situations, it may be converted into equivalent rectangles or triangles (see chapter 2.1.5).

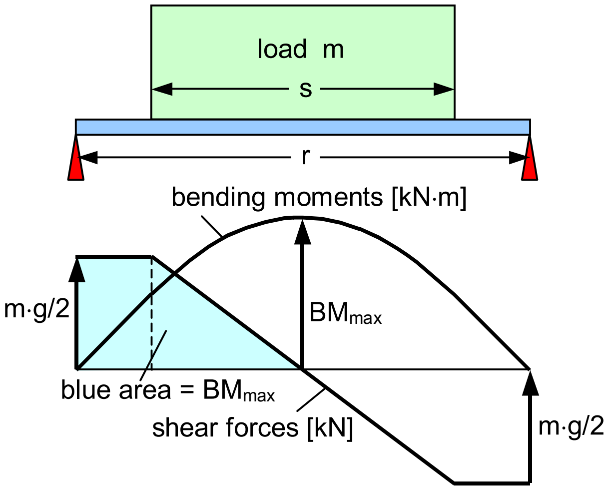


Figure 2.1: Beam with single symmetric load

The stresses in the beam depend on the geometrical properties of its cross-section. These are the cross-sectional area A [cm^2] and the section modulus W_X for vertical bending [cm^3] (see chapter 2.2). The maximum stresses are calculated:

Shear stress: $\tau_{max} \approx \frac{SF_{max}}{A}$ [kN/cm^2] ; Bending stress: $\sigma_{max} = \frac{BM_{max}}{W_X}$ [kN/cm^2]

The final question for the acceptability of the entire load situation may be answered with consideration of the permissible stresses. These depend on the material of the beam (timber, mild steel, high tensile steel) and should generally not exceed the elastic range of the material.

2.1.3 Loading on hatch covers and pontoons

Hatch covers and tween deck pontoons rest with their transverse ends on the hatch coaming or on suitable strong fittings at the sides of the cargo space. The covers or pontoons are designed to act as large beams which are able to carry the appropriate PAL plus their own weight under all conditions of sea transport, which includes vertical accelerations from ship motions in heavy weather. In this sense, the homogeneous loading with PAL produces a bending moment in the cover or pontoon, which presents a limit, that must not be exceeded by any other load configuration with a restricted foot print.

Therefore, if one or several heavy units with narrow foot prints shall be loaded on a hatch cover or tween deck pontoon, it is **not** the primary task to spread the load of each foot print onto an area that satisfies the PAL-requirement. Instead it is necessary to transfer the weight from each footprint to the primary girders of the hatch cover or pontoon in order to utilise its overall bending resistance. This can be occasionally done by using the foot print itself, if it reaches over the main girders of the hatch cover or pontoon.

For a rough reference, Figure 2.2 shows different point loads on a pontoon, which create the same bending moment as a homogeneous load of the mass m. The positions of the point loads are given in percentages of the width of the pontoon. Any concentration of mass or position towards the middle of the beam causes the bending moment to increase. It is important, that the loads are spread over the whole length of the pontoon (orange line) by timber or steel beams.

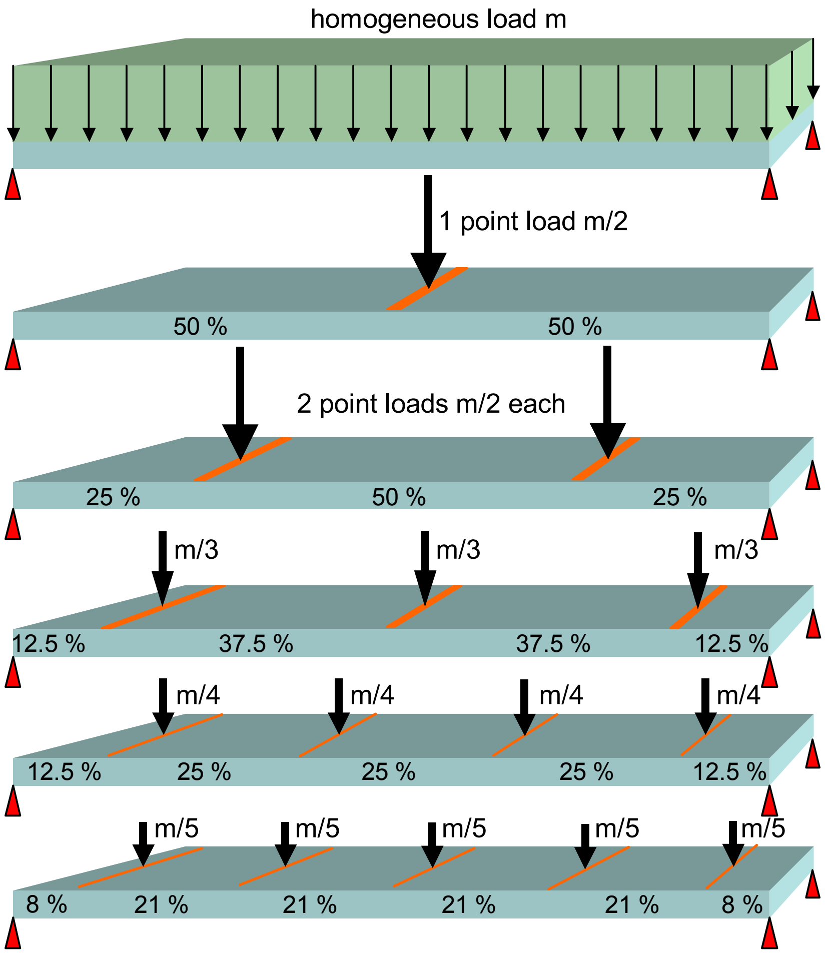


Figure 2.2: Homogeneous load m and different point loads producing the same bending moment in a beam resting on its ends.

2.1.4 Permissible bending moment

The permissible bending moment from the uniform PAL may be obtained by a simple formula.

$$BM_{lim} = \frac{PAL \cdot w^2 \cdot t \cdot g}{8}\ [kN \cdot m]$$

- PAL = permissible area load [t/m^2]
- w = transverse width of the cover [m]
- t = length of the cover in longitudinal ship direction[m]
- g = 9.81 m/s^2

If the hatch cover is equipped with container sockets, the permissible bending moment in the way of a distinguished container bay may be similarly obtained by another formula.

$$BM_{lim} = \frac{n \cdot m_s \cdot w \cdot g}{8}\ [kN \cdot m]$$

- n = number of container stacks on the cover (also partial)
- m_s = permissible stack mass [t/stack]
- w = transverse width of the cover [m]
- g = 9.81 m/s^2

Calculated examples:

The main tween deck pontoons of the "Asia"-Type vessels have the dimensions w = 16.1 m, t = 6.3 m and PAL = 3 t/m^2. The maximum homogeneous load is:

$$m = 3 \cdot 16.1 \cdot 6.3 = 304 \text{ t}$$

The permissible bending moment is:

$$BM_{lim} = \frac{3 \cdot 16.1^2 \cdot 6.3 \cdot 9.81}{8} = 6007 \text{ kN} \cdot \text{m}$$

A weather deck hatch cover of the "Asia"-Type vessels is strengthened between the container bays 11 and 13 for carrying the ends of six plus two half stacks of 20'-containers of maximum 60 t each. Thus the strong transverse girder under the container sockets is designed for a total transverse load of 7 · 60 = 420 t. The permissible bending moment is:

$$BM_{lim} = \frac{7 \cdot 60 \cdot 16.1 \cdot 9.81}{8} = 8292 \text{ kN} \cdot \text{m}$$

These figures should be used as a reference, if the bedding of any non-homogeneous load at this stowage place is considered.

2.1.5 Bending moment of actual loading situation

The actual significant bending moment on a hatch cover or pontoon, caused by one or several cargo units, should be checked by calculation and compared with the value of BM_{lim}.

One single cargo unit

If there is only one cargo unit on the area of consideration, simple formulae may be used for obtaining the actual bending moment.

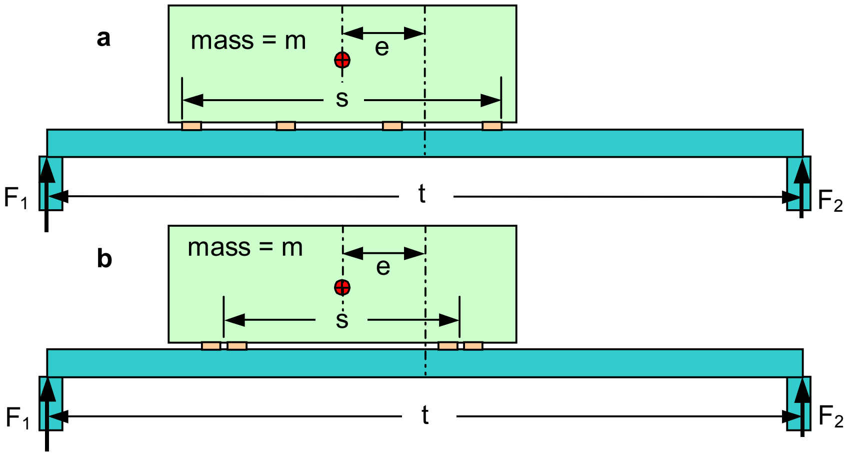


Figure 2.3: Single concentrated load on a hatch cover or pontoon

For a situation as in Figure 2.3.a (load contact over the full distance "s") the bending moment is:

$$BM = \frac{m \cdot g}{8} \cdot (2 \cdot t - s) \cdot \left(1 - \frac{4 \cdot e^2}{t^2}\right) \text{ [kN·m]}$$

For a situation as in Figure 2.3.b (load bridging the distance "s") the bending moment is:

$$BM = \frac{m \cdot g}{8} \cdot \left(2 \cdot t - 2 \cdot s - \frac{4 \cdot e}{t} \cdot (2 \cdot e - s)\right) \text{ [kN·m]}$$

In both situations the supporting forces are:

$$F_1 = \frac{m \cdot g}{2} \cdot \left(1 + \frac{2 \cdot e}{t}\right) [\mathrm{kN}] \qquad \text{and} \qquad F_2 = \frac{m \cdot g}{2} \cdot \left(1 - \frac{2 \cdot e}{t}\right) [\mathrm{kN}]$$

If the unit is placed in the middle of the hatch cover or pontoon with an offset e = 0, all the formulae are considerably simplified. Ignoring a minor offset may be tolerated.

Calculated examples:

A cargo unit of 244 t with a bedding length of s = 9.6 m is stowed athwart ship centrally on a tween deck pontoon. The bedding consists of steel beams laid at uniform distances, so that the load contact covers the full bedding length s. The transverse width of the pontoon is t = 16.1 m. The bending moment is calculated with an offset e = 0:

$$BM = \frac{244 \cdot 9.81}{8} \cdot (2 \cdot 16.1 - 9.6) = 6762\ \mathrm{kN \cdot m}$$

This result exceeds the BM_{lim} of 6007 kN·m (see example in chapter 2.1.3) and is not acceptable. An alternative stowage position with an offset e = 2.8 m is considered:

$$BM = \frac{244 \cdot 9.81}{8} \cdot (2 \cdot 16.1 - 9.6) \cdot \left(1 - \frac{4 \cdot 2.8^2}{16.1^2}\right) = 5944\ \mathrm{kN \cdot m}$$

This result would be acceptable. Another option would be a central position with the cargo unit on steel beams concentrated to its ends, so that a gap of s = 6.2 m is provided. In this way the cargo unit may bridge the middle of the pontoon, thereby reducing the bending moment.

$$BM = \frac{244 \cdot 9.81}{8} \cdot (2 \cdot 16.1 - 2 \cdot 6.2) = 5924\ \mathrm{kN \cdot m}$$

Also this result is acceptable, provided the stiffness of the cargo unit permits a straddled bedding to the ends.

It should be noted, that both permissible options in the example are close to the limit. Thus additional cargo must not be stowed on that pontoon.

Two or more cargo units

In a loading situation with more than one cargo unit, a graphical analysis of the vertical shear forces must be carried out in order to obtain the critical bending moment. At first the bearing forces at the ends of the cover or pontoon should be calculated as follows (see Figure 2.4):

$$F_2 = g \cdot \frac{m_1 \cdot a_1 + m_2 \cdot a_2 + \ldots}{w} \quad [\mathrm{kN}]$$

$$F_1 = g \cdot \sum (m_1 + m_2 + \ldots) - F_2 \quad [\mathrm{kN}]$$

The shear force curve should be drawn as shown in Figure 2.4. The area under the shear force curve from the left side up to the zero position represents the actual maximum bending moment, which is located at that position. The vertical dimension of the area is force, measured in kN, the horizontal dimension is length, measured in metres. The bending moment is therefore obtained in kN·m. It should be checked with the BM_{lim} obtained for the distinguished hatch cover section or tween deck pontoon.

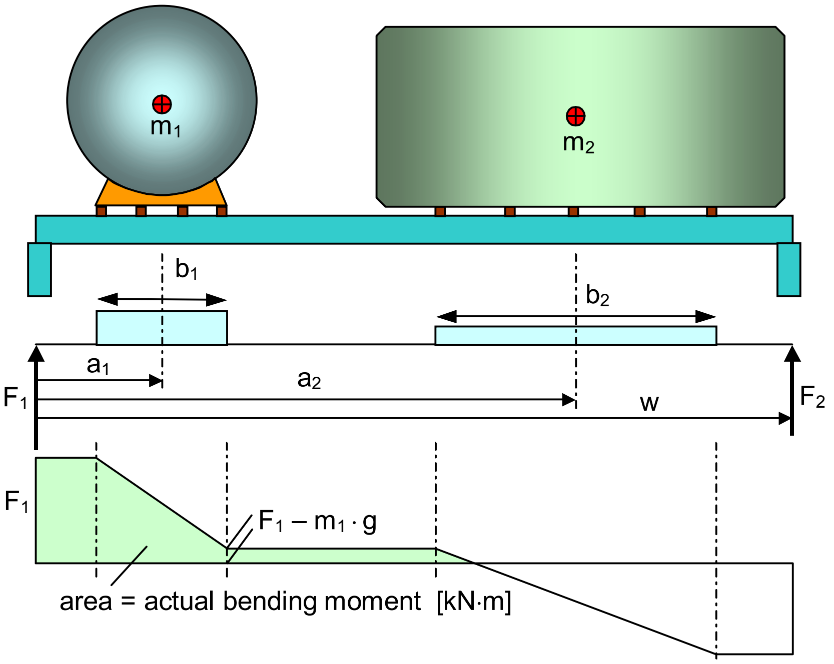


Figure 2.4: Determination of the actual bending moment

Calculated example:

The cargo units in Figure 2.4 are stowed on the weather deck hatch cover in the way of bay 15 with the weight resting on the forward and aft transverse girders under the container sockets of that bay. The permissible bending moment is 8292 kN·m (see example in chapter 2.1.3), if only half of the capacity of each girder is used and the other half left for adjacent cargo. If there is no adjacent cargo to fore and aft, the permissible bending moment may be doubled.

Width of hatch cover w = 16.1 m; cargo data:
m_1 = 196 t; width of bedding b_1 = 2.8 m; a_1 = 2.7 m
m_2 = 240 t; width of bedding b_2 = 6.0 m; a_2 = 11.6 m

$$F_2 = 9.81 \cdot \frac{196 \cdot 2.7 + 240 \cdot 11.6}{16.1} = 2018.8 \quad \text{kN}$$

$$F_1 = 9.91 \cdot (196 + 240) - 2018.8 = 2258.4 \quad \text{kN}$$

The bending moment (area under the shear force curve) is calculated:

Rectangle: $A_1 = 2258.4 \cdot (2.7 - 1.4) = 2935.9 \text{ kN} \cdot \text{m}$

Trapezium: $A_2 = 2.8 \cdot 0.5 \cdot (2 \cdot 2258.4 - 196 \cdot 9.81) = 3631.7 \text{ kN} \cdot \text{m}$

Rectangle: $A_3 = (2258.4 - 196 \cdot 9.81) \cdot (11.6 - 2.7 - 3.0 - 1.4) = 1510.4 \text{ kN} \cdot \text{m}$

Triangle: $A_4 = 0.5 \cdot (2258.4 - 196 \cdot 9.81) \cdot \dfrac{6 \cdot (2258.4 - 196 \cdot 9.81)}{240 \cdot 9.81} = 143.5 \text{ kN} \cdot \text{m}$

Bending moment BM = A_1 + A_2 + A_3 + A_4 = 8221.5 kN·m. This is well in the range of the capacity of bay 15 alone.

2.1.6 Loading on lower hold tank top

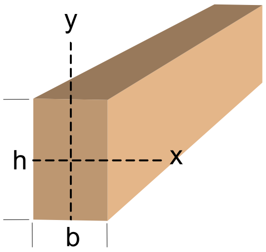
The double bottom of dry cargo ships consist of a grid of longitudinal and transverse beams which is fully supported by the hydrostatic pressure of the surrounding sea-water below. Therefore its structure is much less sensitive against local inhomogeneous loads and will not fail as a whole if locally overloaded. However, in order to avoid local damages, it is advisable to use timber or steel beams to spread the load to an area that satisfies the PAL-requirement. In doing so, it is prudent to place the load spreading beams across the main girders of the double bottom grid structure. The direction of the main girders may be taken from ship yard information (e.g. drawings of double bottom steel structure).

2.2 Bedding material

Bedding equipment may be used for either simply spreading the given load of a heavy cargo unit onto a greater area or purposefully transferring the load onto the main girders of the hatch cover or tween deck pontoon. It is important to take a correct decision on the necessary number and bending resistance of beams for the specific situation.

2.2.1 Timber beams

The bending resistance of beams in general is characterised by their section modulus and their tensile strength. The section modulus is a geometrical figure and can be easily calculated for beams with a rectangular cross-section like timber beams:



$$W_x = \frac{b \cdot h^2}{6} \quad [cm^3]$$

Figure 2.5: Timber beam cross-section

It should be noted that timber beams are available by their nominal dimensions. The true dimensions are generally less due to the width of saw cut and shrinkage. Timber beams should be used with a square cross-section in order to avoid toppling.

The permissible tensile stress of **conifer timber** should be put to σ_p = 1 kN/cm^2. Typical dimensions and associated section modules are shown in the table below.

nominal cross-section [cm^2]	10 x 10	15 x 15	20 x 20	25 x 25
actual cross-section [cm^2]	9.6 x 9.6	14.6 x 14.6	19.5 x 19.5	24.5 x 24.5
section modulus [cm^3]	147	519	1236	2451
mass per metre [kg/m]	5	12	21	33

2.2.2 Steel beams

The permissible tensile stress of **mild steel** with a yield strength of about 23 kN/cm^2 should be rated to σ_p = 15 kN/cm^2 for keeping a safety margin for vertical accelerations to the cargo at sea.

For steel beams of high tensile steel with a higher yield strength, the permissible tensile stress should not exceed 65% of the appropriate yield strength.

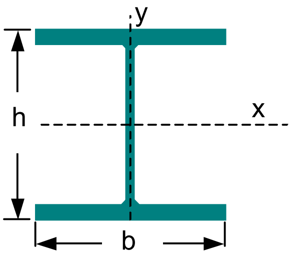


Figure 2.6: Steel beam type HEB cross-section

The dimensions and associated section modules for type HEB are shown in the table below.

h x b [cm]	Wx [cm^3]	Wy [cm^3]	mass per metre [kg]
10 x 10	90	34	20.4
12 x 12	144	53	26.7
14 x 14	216	79	33.7
16 x 16	311	111	42.6
18 x 18	426	151	51.2
20 x 20	570	200	61.3
22 x 22	736	258	71.5
24 x 24	938	327	83.2
26 x 26	1150	395	93.0
28 x 28	1380	471	103.0
30 x 30	1680	571	117.0
32 x 30	1930	616	127.0
34 x 30	2160	646	134.0
36 x 30	2400	676	142.0
40 x 30	2880	721	155.0

Beams may be used as twin beams, if deemed appropriate in order to avoid wobbling or rolling under severe conditions.

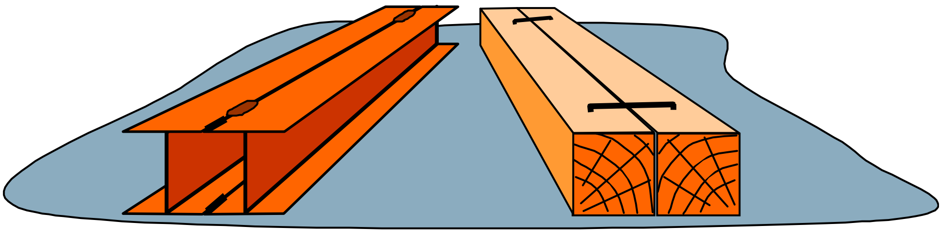


Figure 2.7: Twin beams of steel and timber

2.2.3 Required number of beams

The required number of beams should be determined by means of formulae with due regard to the bedding condition A or B. In condition A, the beams are placed with their full length on the stowage ground (Figure 2.8).

Required number of beams in **condition A**: $n = \frac{m \cdot g \cdot (r - s) \cdot 100}{8 \cdot \sigma_p \cdot W_x}$

- m = mass of cargo unit [t]
- g = gravity of earth [9.81 m/s^2]
- r = supported length of beam [m]
- s = loaded length of beam [m]
- σ_p = permissible tensile stress [kN/cm^2]
- W_x = section modulus of beam [cm^3]

The above formula may be customised for timber beams and steel beams as follows:

For timber beams: $n = \frac{m \cdot g \cdot (r - s) \cdot 100}{8 \cdot W_x}$; for steel beams: $n = \frac{m \cdot g \cdot (r - s) \cdot 100}{120 \cdot W_x}$

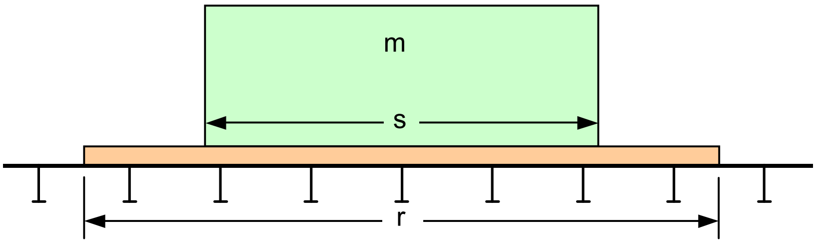


Figure 2.8: Load spreading condition A

The effective length of beams in condition A is limited by their tendency to deflect more than the tank top or deck below. The following table should be used to check the suitable length r against the loaded length s.

timber beams 10 x 10 cm:	$r_{max} = (1.2 \cdot s + 0.8)$ m,	but not more than $(s + 1.0)$ m
timber beams 15 x 15 cm:	$r_{max} = (1.2 \cdot s + 1.5)$ m,	but not more than $(s + 2.0)$ m
timber beams 20 x 20 cm:	$r_{max} = (1.2 \cdot s + 2.0)$ m,	but not more than $(s + 3.0)$ m
timber beams 25 x 25 cm:	$r_{max} = (1.2 \cdot s + 2.4)$ m,	but not more than $(s + 4.0)$ m
steel beams 12 x 12 cm:	$r_{max} = (1.2 \cdot s + 3.0)$ m,	but not more than $(s + 4.0)$ m
steel beams 14 x 14 cm:	$r_{max} = (1.2 \cdot s + 3.2)$ m,	but not more than $(s + 4.2)$ m
steel beams 16 x 16 cm:	$r_{max} = (1.2 \cdot s + 3.4)$ m,	but not more than $(s + 4.4)$ m
steel beams 18 x 18 cm:	$r_{max} = (1.2 \cdot s + 3.6)$ m,	but not more than $(s + 4.6)$ m
steel beams 26 x 26 cm:	$r_{max} = (1.2 \cdot s + 4.0)$ m,	but not more than $(s + 5.0)$ m
steel beams 30 x 30 cm:	$r_{max} = (1.2 \cdot s + 5.0)$ m,	but not more than $(s + 6.0)$ m

If beams are used to bridge the weak area of a hatch cover between the strengthened transverse segments of the container sockets (Figure 2.9), the number of required beams must be increased due to the lack of intermediate support. This is the condition B, which almost inevitably requires steel beams for practical reasons.

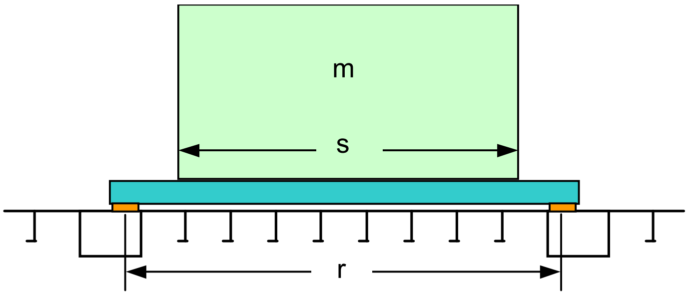


Figure 2.9: Load spreading condition B

Required number of beams in **condition B**: $n = \dfrac{m \cdot g \cdot (2 \cdot r - s) \cdot 100}{8 \cdot \sigma_p \cdot W_x}$

- m = mass of cargo unit [t]
- g = gravity of earth [9.81 m/s^2]
- r = distance between supports of beam [m]
- s = loaded length of beam [m]
- σ_p = permissible tensile stress [kN/cm^2]
- W_x = section modulus of beam [cm^3]

The above formula may be customised for timber beams and steel beams as follows:

For timber beams: $n = \dfrac{m \cdot g \cdot (2 \cdot r - s) \cdot 100}{8 \cdot W_x}$; for steel beams: $n = \dfrac{m \cdot g \cdot (2 \cdot r - s) \cdot 100}{120 \cdot W_x}$

If the beams in condition B are loaded with an offset e from their middle, the bending stress is reduced and less beams may be required.

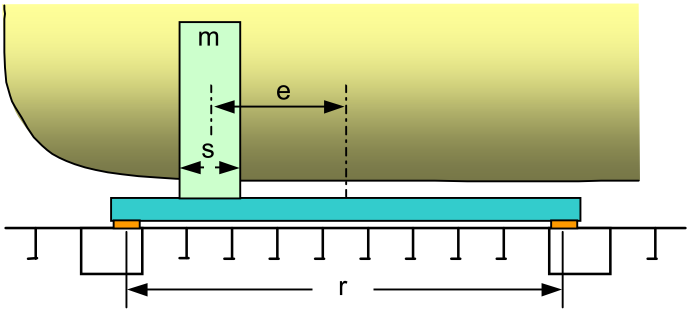


Figure 2.10: Load spreading condition B with offset e

Required number of beams condition B with offset: $$n = \frac{m \cdot g \cdot (2 \cdot r - s) \cdot 100}{8 \cdot \sigma_p \cdot W_x} \cdot \left(1 - \frac{4 \cdot e^2}{r^2}\right)$$

- e = offset from middle of beam [m]

Calculated examples:

A transformer of 346 t with a foot print of 4.8 x 3.6 = 17.28 m^2 shall be loaded on the lower hold tank top. The PAL is 16 t/m^2. In order to spread the load onto a greater area, the transformer shall be placed on steel beams of 26 x 26 cm and a length of 5.0 m. The direction of the beams goes with the width of s = 3.6 m, so that the beams with r = 5.0 m protrude 0.7 m on each side. The required number of beams is:

$$n = \frac{346 \cdot 9.81 \cdot (5.0 - 3.6) \cdot 100}{8 \cdot 15 \cdot 1150} = 3.44 \Rightarrow 4$$

Four beams are sufficient. The length is well within the limit of r_{max} = 1.2 · 3.6 + 4.0 = 8.3 m. The loaded area of the tank top is now 4.8 x 5.0 = 24 m^2, providing an area load of 14.4 t/m^2.

The footprint of a long cargo unit with the partial load of 40 t and a length s = 0.6 m shall be placed between the strong girders under the container sockets on a weather deck hatch cover with an offset e = 1.6 m (see Figure 2.10). The length of the steel beams is 6.2 m, the dimension is 20 x 20 cm. The required number of beams is:

$$n = \frac{40 \cdot 9.81 \cdot (2 \cdot 6.2 - 0.6) \cdot 100}{8 \cdot 15 \cdot 570} \cdot \left(1 - \frac{4 \cdot 1.6^2}{6.2^2}\right) = 4.97 \Rightarrow 5$$

Five beams must be used.

2.2.4 Steel plates

Steel plates may be used to avoid local denting of the plating of hatch covers, tween deck pontoons or tank tops from concentrated loads. It should be kept in mind that the load spreading capacity of steel plates is quite limited and generally not sufficient to effectively transfer a point load to structural primary or secondary girders of the stowage ground.

Therefore steel plates should be only used to satisfy the PAL-requirement at a small range, preferably together with a floor of timber beams underneath. The primary field of using steel plates is the stowage or transfer of rubber-wheel based cargo units, like rubber tyre gantry cranes (RTG's), on top of weather deck hatch covers.

The required dimensions (length, breadth and thickness) of such plates depend on the load to the footprint, the size of the footprint and the desired area enlargement factor. Any decision regarding the application of steel plates for bedding purposes should be left to the cargo planning department of BBC Chartering.

2.2.5 *ISO-platforms or flatracks*

If ISO-flatracks or platforms are used for bedding heavy cargo units, their bending resistance (section modulus) is generally unknown. Instead, their specified **pay load**, i.e. the maximum permissible homogeneous load, may be used to determine permissible concentrated loads.

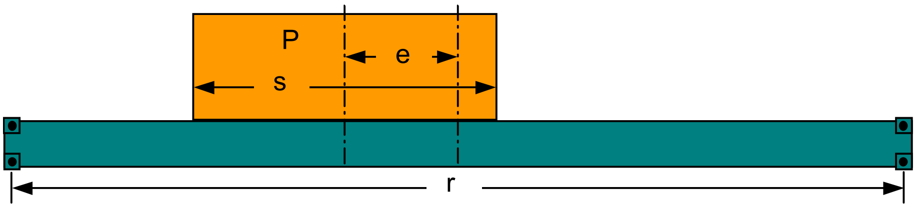


Figure 2.11: Asymmetric loading of a platform

The characteristics of any inhomogeneous loading of a platform consist of the loaded length s and a possible offset e from the centre of the platform (Figure 2.11). With these two parameters s and e, the permissible concentrated load P may be determined by applying the factor from the appropriate table for 20' or 40' flatracks to the nominal pay load P_0.

$$P = P_0 \cdot \text{factor} \quad [t]$$

Table of factors for loading a 20'-platform or flatrack

s	**offset e [m]**					
[m]	**0.0**	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**
1	**0.55**	**0.56**	**0.61**	**0.73**	**0.98**	**1.79**
2	**0.60**	**0.62**	**0.68**	**0.80**	**1.08**	
3	**0.67**	**0.69**	**0.75**	**0.89**		
4	**0.75**	**0.77**	**0.84**			
5	**0.86**	**0.88**				
6	**1.00**					

Table of factors for loading a 40'-platform or flatrack

s	**offset e [m]**											
[m]	**0.0**	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**	**5.0**	**5.5**
1	**0.52**	**0.53**	**0.54**	**0.56**	**0.59**	**0.63**	**0.70**	**0.79**	**0.94**	**1.19**	**1.71**	**3.27**
2	**0.55**	**0.55**	**0.56**	**0.58**	**0.61**	**0.66**	**0.73**	**0.83**	**0.98**	**1.25**	**1.79**	
3	**0.57**	**0.58**	**0.59**	**0.61**	**0.64**	**0.69**	**0.76**	**0.87**	**1.03**	**1.31**		
4	**0.60**	**0.60**	**0.62**	**0.64**	**0.68**	**0.73**	**0.80**	**0.91**	**1.08**			
5	**0.63**	**0.64**	**0.65**	**0.67**	**0.71**	**0.76**	**0.84**	**0.96**				
6	**0.67**	**0.67**	**0.69**	**0.71**	**0.75**	**0.81**	**0.89**					
7	**0.71**	**0.71**	**0.73**	**0.75**	**0.79**	**0.85**						
8	**0.75**	**0.76**	**0.77**	**0.80**	**0.84**							
9	**0.80**	**0.81**	**0.82**	**0.85**								
10	**0.86**	**0.86**	**0.88**									
11	**0.92**	**0.93**										
12	**1.00**											

If a heavy load is placed on a flatrack of platform bridging the distance s, the permissible load may be determined by the formula:

$$P = P_0 \cdot \frac{r}{2 \cdot r - 2 \cdot s} \quad [t]$$

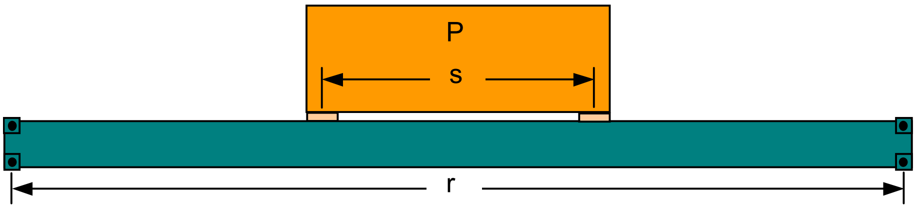


Figure 2.12: Load P bridging the distance s on a platform

It should be noted that this formula may provide figures of P much greater than P_0, if $s > r/2$. This is correct for the bending stress in the flatrack or platform. In that case, however, the point loads at the corner castings to the foundations of the stowage place should be considered for limiting the load P.

Flatracks and platforms of 40 foot length have a built-in hogging deflection of about 2.5 cm. They should be flat under the full pay load. A negative deflection in loaded condition is already a sign of overloading.

Calculated examples:

A 20'-flatrack with payload $P_0 = 32$ t shall be centrally ($e = 0$) loaded with a cargo unit of 26 t and a base length of $s = 3$ m. The applicable table shows a loading factor of 0.67. The permissible load P is calculated.

$$P = P_0 \cdot 0.67 = 32 \cdot 0.67 = 21.44 \text{ t}$$

For placing 26 t, a factor 26/32 = 0.81 is required. This factor would be obtained by either spreading the load with timber beams to a length s = 4.6 m (see table above) or by placing it with an offset e = 1.2 m from the middle (see table above).

A third option would be bridging a space of s = 2.3 m (see Figure 2.12) and using the formula with r = 5.85 m (length between centres of corner castings):

$$P = P_0 \cdot \frac{r}{2 \cdot r - 2 \cdot s} = 32 \cdot \frac{5.85}{11.70 - 4.60} = 26.4 \text{ t}$$

This option is only feasible, if the cargo unit has sufficient stiffness for bridging an s = 2.3 m.

3. Securing standards

3.1 General principles

3.1.1 External forces

External forces to the cargo during the seagoing passage can be derived from three sources:

- **gravity forces** with their components in the transverse and longitudinal direction of the ship's co-ordinate system due to rolling or pitching,
- **inertia forces** on cargo units due to accelerations of the ship, which is the physical reference system for the cargo,
- **impact forces** resulting from the impact of wind or heavy water spray on cargo units stowed on deck.

Gravity forces and inertia forces increase with the mass of a cargo unit, while impact forces depend on the area of a cargo unit exposed to wind or heavy water spray.

Forces from the above sources act as a combined vector within a three dimensional co-ordinate system of the ship, together with the gravity component on to the stowage area. For checking the suitability of a securing arrangement, the three components of this vector are considered separately.

F_x = longitudinal force [kN],
F_y = transverse force [kN],
F_z = vertical force [kN].

In general, ships tend either to roll heavily or to pitch heavily. But there may be simultaneous motions in both ways. Therefore, peak values of forces in the transverse direction may appear in combination with up to 60% of peak values in the longitudinal and the vertical direction and vice versa. However, peak values in the longitudinal direction and in the vertical direction may appear together with 100% each, because of their common sources from pitching and heaving motions.

The magnitude of forces to be expected during a voyage depends on a number of circumstances and parameters:

- weather, wind and sea conditions,
- duration of the voyage,
- properties of the ship in terms of size, stability and speed,
- longitudinal and vertical location of stowage,
- stowage on deck or under deck,
- mass of the cargo unit,
- dimensions of the cargo unit.

The magnitude of forces in an actual application is obtained by a calculation rule in the Annex 13 to the IMO CSS-Code. The assumption of these forces and the appropriate securing of the cargo will guarantee a safe transport in principle. However, masters should bear in mind the warnings given in the Annex 13 with regard to possible higher forces. These warnings are:

- *In the case of marked roll resonance with amplitudes above ± 30°, the given figures of transverse accelerations may be exceeded. Effective measures should be taken to avoid this condition.*
- *In the case of heading into the seas at high speed with marked slamming shocks, the given figures of longitudinal and vertical accelerations may be exceeded. An appropriate reduction of speed should be considered.*
- *In the case of running before large stern or quartering seas with a stability which does not amply exceed the accepted minimum requirements, large roll amplitudes must be expected with trans-*

verse accelerations greater than the figures given. An appropriate change of heading should be considered.

For the transport of cargo units of outstanding dimensions – essentially deck cargo – the calculation approach of the Annex 13 for the tipping moment should be supplemented by considering the "additional tipping moment" produced by the rotational inertia of the cargo unit. Details of this complementary calculation are shown in chapter 3.4.7.

3.1.2 Aims of securing

Securing of cargo shall guarantee that the cargo keeps in place, does neither topple nor collapse, and remains intact throughout the voyage. Technically, the following incidents must be avoided and kept in mind, when planning and/or assessing a securing arrangement:

- transverse sliding,
- longitudinal sliding,
- transverse tipping,
- longitudinal tipping,
- excessive racking,
- collapsing of a stack of cargo,
- floating up of deck cargo,
- local damage in form of scratches, dents, cuts, corrosion and others.

Project cargo, in particular heavy units, must be secured by a **direct transfer of forces** from the cargo unit to the ship. Any other securing technique, in particular "down-strapping" for increasing the friction at the bottom, or "compacting" for combining smaller cargo units to a bigger block, are inappropriate for securing project cargo units.

Direct transfer of forces may only be achieved by:

- lashing with wire rope, chain or web (synthetic fibre),
- timber shoring,
- welding stoppers or stanchions,
- setting twist locks into ISO-flatracks, platforms or tailor-made steel foundations.

The main emphasis must be placed on the prevention of sliding, followed by the prevention of tipping. Excessive racking may appear only if a cargo unit of weak structure is fastened at the bottom and suffers deformation from external forces affecting the centre of gravity above.

3.1.3 Friction

Friction between a cargo unit and the stowage place is a natural means to support sliding prevention. Therefore, timber dunnage or plywood must be used for avoiding any steel to steel contact of a cargo footprint to the stowage place, unless the footprint is placed on timber beams for load spreading. If steel beams are used for load spreading, timber dunnage or plywood must also be placed under the beams, unless the beams are effectively secured to the stowage area by welding or shoring.

Friction may generally be impaired by wet dirt, dry dust, remains of oil or grease, by short period vibration and by single shocks. For this reason, the friction coefficients agreed to in the IMO CSS-Code are conservative, if compared to figures from laboratory conditions.

If single pieces of project cargo are stacked one upon each other and shall be secured as a bundle, e.g. steel construction elements, sufficient timber dunnage or plywood must be placed between the individual units in order to stabilise the stack by means of friction.

In certain stowage positions in the ship, e.g. lower hold or tween deck level in the midship section, friction alone may be sufficient for avoiding longitudinal sliding. However, care should be taken, that this friction is supported by some vertical components of transverse lashings for stabilising the cargo unit against vibration or shocks.

Stowage positions in the forward part of the ship may suffer from substantial vertical accelerations, which periodically decrease the weight of a cargo unit and thereby reduce the friction. These accelerations may appear together with longitudinal forces, when steering into heavy seas. Therefore friction alone will fail to prevent longitudinal movement in these stowage locations and must be adequately upgraded or replaced by other securing means.

3.2 Securing equipment

Securing equipment for direct securing acts by its strength. The nominal breaking strength or breaking load (BL) is a figure generally supplied by the manufacturer or chandler and documented in a type certificate. It is also contained in the ship's inventory list. For securing employment the strength boundary line is the "maximum securing load" (MSL). The Annex 13 to the IMO CSS-Code provides a table showing MSL as a percentage of BL for different securing elements.

Material	MSL
shackles, rings, deck eyes, turnbuckles of mild steel	50% of breaking strength
fibre ropes	33% of breaking strength
web lashings	50% of breaking strength
wire rope (single use)	80% of breaking strength
wire rope (re-useable)	30% of breaking strength
steel band (single use)	70% of breaking strength
chains of high tensile steel	50% of breaking strength
timber	0.3 kN per cm^2 normal to the grain

3.2.1 Lashings

BBC-Chartering uses three types of lashings of different strength and elasticity. The most versatile is the wire rope lashing, connected by bulldog-clips and tensioned by a turnbuckle, followed by chain lashings with lever tightener and web lashings with ratchet tightener.

Wire rope lashings

There are three permissible options of assembling a wire rope lashing for securing project cargo.

The **Type A lashing** is the most common and easy to assemble in a convenient working position. The clips are set after the free wire ends are bent through the turnbuckle. Three clips on each end are necessary for heavy duty service with the usual wire diameter of 16 to 18 mm. A strength reduction due to the narrow bend in the turnbuckle is avoided by doubling the wire in this bend. If there is a narrow bend on the other end, the strength is reduced according to the table below.

The **Type B lashing** is a suitable alternative, if only low capacity turnbuckles are available. The double turn at the lower end of the turnbuckle allows the use of two clips only, while another three are needed at the upper end of the turnbuckle. Again, a strength reduction to the double wire must be considered, if the upper turn of the wire rope is a narrow bend.

The **Type C lashing** is the option for long lashings, e.g. lashings going around a cargo unit in the way of a "half loop". For obtaining the same strength as the other types, the diameter of the wire should be about 1.4 times greater. There is no strength reduction in narrow bends, as the wire is doubled in both ends.

The **"La Paloma" Type** is unreliable due to the missing bends at the wire connection. Even with six clips its holding capacity would be less than that of the other types. It is **not** accepted by BBC Chartering.

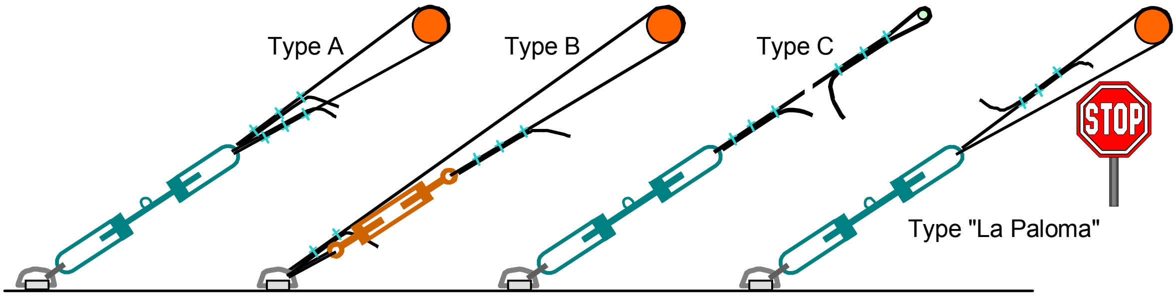


Figure 3.1: Types of wire rope lashings

The strength reduction in narrow bends may be estimated by figures from the table below. In short lashings of Types A and B, which simply connect securing points on a cargo unit and on the ship, the wire is steady in the bend. However, if a lashing is going around a large cargo unit and has to pass narrow bends or corners, the elasticity of the wire rope causes a permanent movement at these corners. Therefore it must be considered as slipping in the bend.

Table for **residual strength** of wire rope lashings after a narrow bend

ratio b/d	**0.5**	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**	**4.5**	**5.0**
rope steady in the bend	50%	65%	72%	77%	81%	85%	89%	93%	96%	99%
rope slipping in the bend	25%	50%	60%	65%	70%	75%	79%	83%	87%	90%

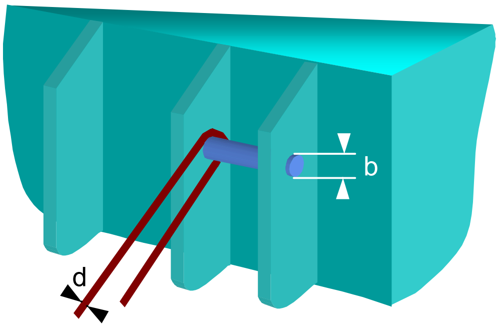


Figure 3.2: Residual strength of wire rope after a narrow bend

If wire rope lashings are guided through gaps in ship structures or eye plates on cargo units, there is a further strength reduction due to sharp corners. A turn of 180° with two such corners produces a residual strength of 25% in each part of the wire. It is therefore wise to double the wire in such a situation, if it cannot be avoided altogether.

Wire rope clips should be set in a way that the U-bolts are visibly pressed into the "dead end" of the wire rope. This can only be achieved if the bolts or the nuts are slightly greased. The distance of the clips at the wire rope should not be less than six-times the wire diameter.

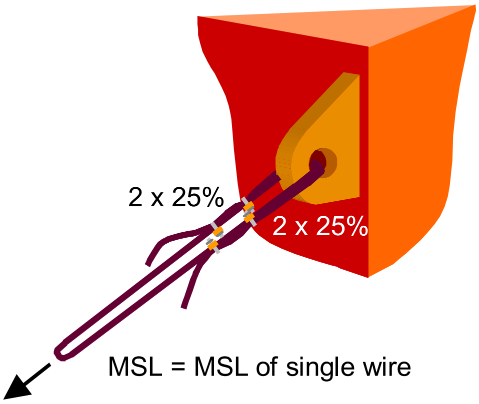


Figure 3.3: Residual strength after sharp corners

The strength of a wire rope lashing is equal to the strength of its weakest component, i.e. the deck ring or eye plate, the shackle, the turnbuckle, the wire or the fitting on the cargo unit.

Calculated example:

A Type A lashing is fixed to a D-ring of MSL = 180 kN with a 32 mm lash shackle of MSL = 157 kN. The M 36 turnbuckle has also an MSL = 157 kN. The 18 mm wire rope of BL = 185 kN is guided around an upper bend of b = 32 mm, which is another lash shackle of MSL = 157 kN. Thus the double wire provides an MSL = 185 · 2 · 0.75 · 0.8 = 222 kN for one-way use. The least MSL-figure is 157 kN. There should be six well tightened wire clips for warranting this MSL for the whole lashing.

Chain lashing with lever tensioner

The common 13 mm long-link chain lashing is supplied with hooks at the ends and with a lever tightener. The correct application shall provide an angle between lever and chain of about 45° but never more than 80°. The re-tightening hook shall not be left engaged with the lever turned to the other side, but only used for re-tightening.

The breaking strength of those long link chains is BL = 200 kN. According to the IMO CSS-Code, the MSL = 100 kN. It should be noted that chains are frequently delivered on board by manufacturers or chandlers with a certified WLL = 80 kN according to class-rules for container securing. This WLL is directly used within the approval evaluation for containers, while the MSL according to the IMO CSS-Code is reduced to CS = 67 kN for securing balance calculations. So there is no need to apply MSL = WLL to chains for project cargo.

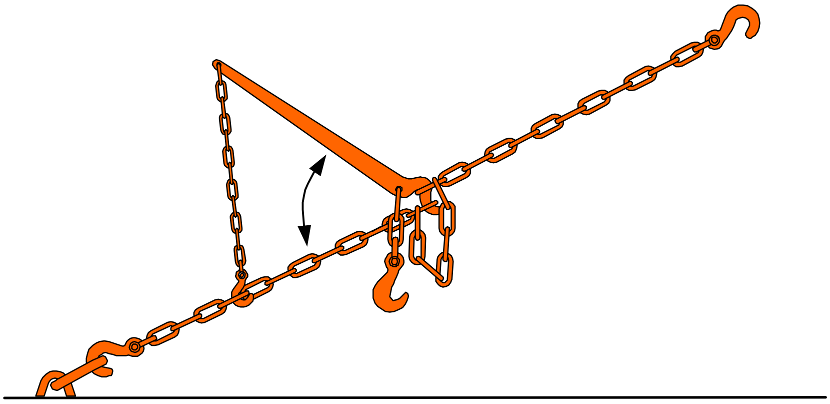


Figure 3.4: Long-link chain lashing with lever tightener and re-tightening hook

Web lashing with ratchet tensioner

Web lashings are used with MSL = 25 and 50 kN in different working lengths. Their elasticity is remarkably greater than that of wire lashings and chains. They should therefore not be used in parallel with them. The high elasticity of web lashings also bears the risk of chafing at corners of cargo units or other structures in the way of the lashing. Care must be taken to avoid this or protective material like rubber sheets or gunny cloth must be applied.

The figure of MSL is generally marked on a blue label under the name LC (load capacity) and given in dN (dekaNewton). 1 kN = 100 dN.

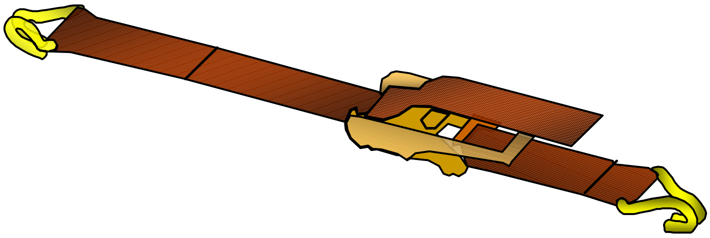


Figure 3.5: Heavy duty web lashing with MSL = 50 kN

3.2.2 *Turnbuckles, shackles, insertable D-rings*

This equipment is used for assembling lashings and is provided with appropriate documents, stating the breaking strength and the MSL. In some cases this equipment is delivered as part of the container securing system (e.g. chain-turnbuckles, insertable D-rings) and attributed a WLL-figure as working load limit. As explained for chains above, this WLL-figure is not necessarily to be used as MSL, unless it is 50% of the breaking strength as allocated by the IMO CSS-Code, Annex 13.

3.2.3 *Welded stoppers and lashing points*

In certain situations welded stoppers are a useful option for protecting a cargo unit against sliding and/or tipping. Also additional lashing plates or D-rings may be needed for applying lashings in purposeful positions. Although these fittings are generally of a temporary nature and will be removed after completing the distinguished transport, they must be thoroughly positioned with regard to the ship structures below the location and the welding itself must be carried out in a professional manner by an external welding company, **not** by the crew of the vessel.

Welding principles

Apart from D-ring saddles, which are welded to the ground by a butt seam, all other types of stoppers and plates are welded by a fillet seam. For assigning an appropriate MSL to such a stopper or lashing point the following conditions are presumed:

- The yield tension for any calculation applies to mild steel of strength class S235 for material thickness of up to 20 mm and is taken for the safety class "Normal" as 180 N/mm^2 or the equivalent 18.0 kN/cm^2. The appropriate permissible shear stress is 10.4 kN/cm^2.
- Welded seams are assumed as "ordinary quality" (class A). The applicable permissible stresses are:

	pull, bending	pressure	shear
butt seam	12.0 kN/cm^2	15.0 kN/cm^2	8.7 kN/cm^2
fillet seam	10.0 kN/cm^2	10.6 kN/cm^2	8.7 kN/cm^2

- The effective area of a welded seam is calculated as length of seam L multiplied by the A-measure. The A-measure of a butt seam is equal to the thickness of the plate. The A-measure of a fillet weld may be measured by means of a welder's gauge. It should amount to at least 6 mm.
- Therefore, the MSL of a fillet seam may be adopted as 5 kN per cm seam length for a shear load and 6 kN per cm seam length for a tensile load, both with A-measure = 6 mm.
- Similarly, the MSL of a butt seam may be adopted as 8.7 kN per cm^2 seam for a shear load and 12 kN per cm^2 seam for a tensile load.

If deemed necessary, other assumptions may be taken by BBC Chartering regarding the safety class, seam quality or A-measure of welded seams, with consequential changes of strength figures. The pertinent calculations will be conducted in the planning office.

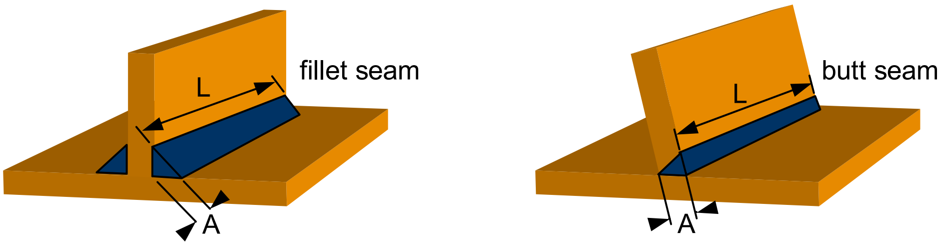


Figure 3.6: Applicable types of welded seams

Plate stoppers

Plate stoppers are used mainly for sliding prevention, if the strong edge of a cargo unit is low. A face plate, tack welded to the stopper plate, is recommended for sensitive cargo units (see Figure 3.7). The appropriate horizontal strength of the stopper may be obtained by the shear stress criterion with $MSL_{xy} = 5 \cdot (2 \cdot L + t)$ [kN].

Example: L = 20 cm, t = 2 cm; MSL_{xy} = 210 kN.

Plate stoppers may also be used to additionally clip a cargo unit vertically against tipping. The welded seam must be fully passed around the plate, because there is a load concentration in the seam end under the clip. It should be noted, that the vertical load MSL_z creates shear stress in the area (h · t) and a bending stress in the base area (L · t) with the bending moment (MSL_z · e). The bending lever e is measured from the shear area to half the length L. The appropriate vertical strength will be obtained by the lesser result of the equations:

$$MSL_z = 10.4 \cdot h \cdot t \text{ [kN]} \quad \text{and} \qquad MSL_z = 6 \cdot 2 \cdot (L + t) \cdot \left(\frac{L}{L + 5 \cdot e}\right) \quad \text{[kN]}$$

Example: L = 18 cm, t = 2 cm, h = 7 cm, e = 8 cm. MSL_{xy} = 5 · 40 = 200 kN. Calculation of MSL_z for the plate: MSL_z = 10.4 · 7 · 2 = 146 kN; for the weld: MSL_z = 6 · 40 · 0.31 = 74 kN. The lesser value of MSL_z = 74 kN must be used.

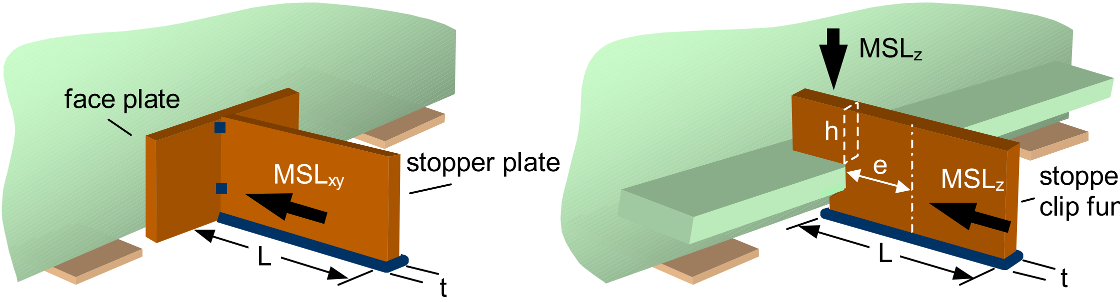


Figure 3.7: Plate stoppers with face plate (left) and with clip function (right)

Low H-beam stoppers

For heavy duty stoppers, pieces of H-beams should be used. They may be welded to the ground either on their face, fully welded around (left), or on the edges of the flanges (right in Figure 3.8). Again, a face plate should be tack welded to the flat stopper, if necessary. The strength of such a stopper may be obtained by the shear stress criterion with $MSL_{xy} = 5 \cdot 6 \cdot b$ [kN] for the low vertical stopper (left) and $MSL_{xy} = 5 \cdot 2 \cdot L$ [kN] for the flat stopper (right).

Example: b = 14 cm; MSL_{xy} = 420 kN (left); L = 50 cm; MSL_{xy} = 500 kN (right).

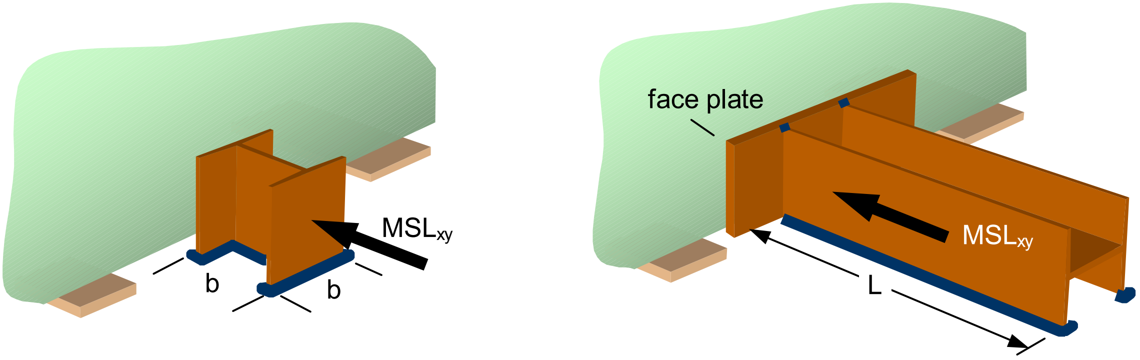


Figure 3.8: Low H-beam stoppers

High H-beam stoppers

If the strong edge of a cargo unit is higher, vertical H-beam stoppers must be used. It is then important, that

- the effective height H of the stopper is not greater than the base length L,
- the whole construction is stabilised by an angle plate,

- the fillet weld is fully passed around the bottom line.

The predominant stress in that construction is the result of the bending moment $MSL_{xy} \cdot H$, which creates a critical vertical tensile stress in the welded seam at the end of the stopper towards the cargo unit.

The construction to the left in Figure 3.9 is easier to build, but less convenient to remove from the ground after use. It is comparably stronger than the construction to the right in Figure 3.9, due to the greater seam density in the critical area of tensile forces. However, with greater height H and length L this construction may become weaker due to the risk of buckling of the long free edge of the triangle plate. Therefore, with figures of $(L - b) > 40$ cm the construction to the right in Figure 3.9 should be considered and/or the triangle plate edge strengthened.

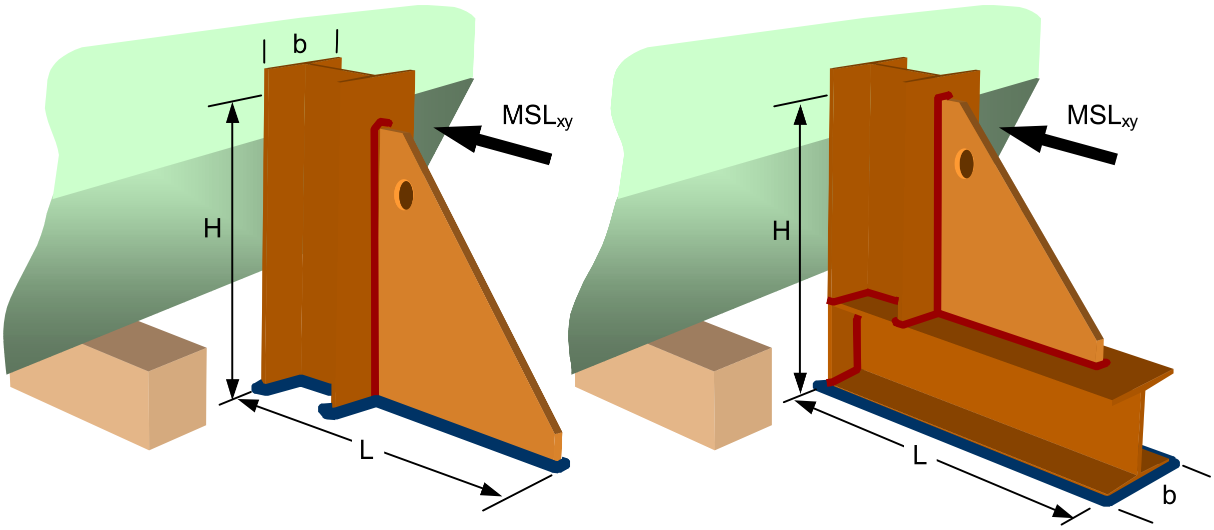


Figure 3.9: High H-beam stoppers.

The applicable strength of these stoppers cannot be obtained by a simple formula. Therefore tables are provided, which show the figures of MSL_{xy} as a function of the length L and the dimensions of the H-beam cross section. The tables are based on a height H that is equal to the length L and an A-measure of the fillet seam of 6 mm. If $H < L$, then the obtained MSL_{xy} may be increased by the factor L/H, but should never exceed the figure obtained by the shear stress criterion with $MSL_{xy} = 5 \cdot 2 \cdot (L+b)$ [kN].

Table: MSL_{xy} [kN] versus length L and dimension of beam in Figure 3.9 (left).

	Dimension of H-beam [cm x cm]										
L [cm]	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**
40	164	173	181	189	199	210	224	241			
50	194	205	215	224	232	240	249	260	273	288	
60			247	257	266	274	282	291	300	311	323
70					299	308	317	325	333	342	351
80							350	359	367	375	384
90									401	409	418
100											452

Table: MSL_{xy} [kN] versus length L and dimension of beam in Figure 3.9 (right).

	Dimension of H-beams [cm x cm]										
L [cm]	**10**	**12**	**14**	**16**	**18**	**20**	**22**	**24**	**26**	**28**	**30**
40	140	152	164	176	188	200					
50	160	172	184	196	208	220	232	244			
60	180	192	204	216	228	240	252	264	276	288	
70			224	236	248	260	272	284	296	308	320

80					268	280	292	304	316	328	340
90							312	324	336	348	360
100									356	368	380

Example: Vertical H-beam stopper (left construction in Figure 3.9) with L = 70 cm and b = 20 cm; MSL_{xy} = 308 kN. If H = 40 cm, then MSL_{xy} = 308 · 70 / 40 = 539 kN. This is less than the limiting value of 900 kN from the shear stress criterion and therefore acceptable.

Angle stoppers and others

For certain cargo units standing low on the ground, so-called angle stoppers may be of advantage. These stoppers are easy to apply and to remove, but do not provide large MSL-figures. The applicable strength figure is valid both in transverse and longitudinal direction and may be obtained by the shear stress criterion with $MSL_{xy} = 5 \cdot 2 \cdot L$ [kN].

Example: L = 15 cm; MSL_{xy} = 150 kN.

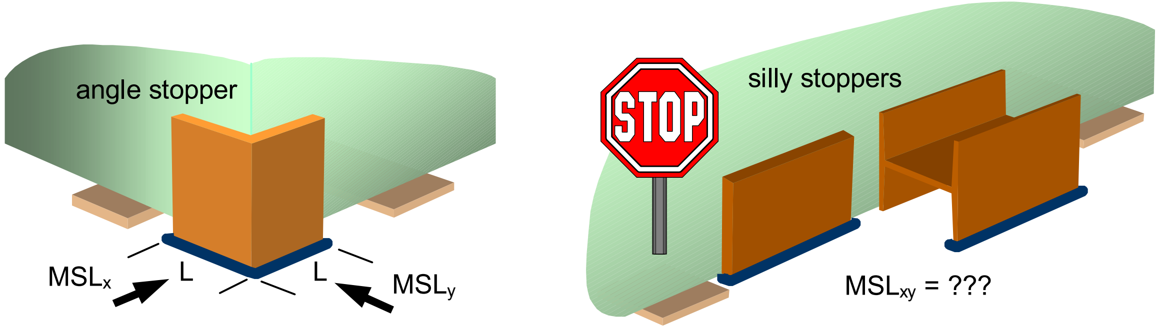


Figure 3.10: Angle stopper (left) and silly stoppers (right)

Simple face plates or pieces of H-beams welded to the ground by a single fillet seam only, which are loaded transverse to the seam (Figure 3.10 right), are not trustworthy and therefore not allowed by BBC Chartering.

Lashing plates and D-rings

Lashing plates and D-ring saddles must be welded to the ground on top of a strengthening scantling below. The plate must be placed in a direction that fits perfectly to the direction of the intended lashing. Only then its strength may be obtained by the shear stress criterion with $MSL = 5 \cdot 2 \cdot (L + t)$ [kN].

Example: L = 15 cm, t = 2 cm; MSL = 170 kN.

D-rings are usually purchased as equipment with a certified breaking strength (BL). However, the butt weld of the saddle must be a good quality full penetration weld with several weld layers and well rounded welds at the ends of the saddle. Only then, MSL = 0.5 · BL as certified.

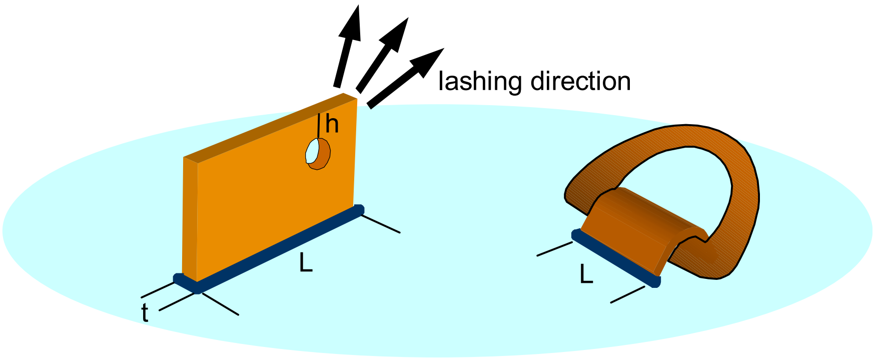


Figure 3.11: Welding a lashing plate (left) and a D-ring (right)

Quality of welding

Welded seams should be visually inspected after the slag has been removed. The inspection should include spot checking the A-measure and looking for seam faults.

The A-measure may be quickly checked by a seam gauge, available for 90° fillet welds. Typical seam faults are described as follows:

- **Seam undercuts** may result from excessive current, wrong electrode angle and/or excessive welding speed.
- **Hot cracks** may result from excessively high current, insufficient preheat and/or high impurity level of base material.
- **Cold cracks** (hydrogen cracks) result mainly from wet electrodes or welding in rainy weather, occasionally from insufficient preheating.
- **Surface porosity** may result from wet electrodes, rusty or dirty base material and/or excessive welding speed.
- **Slag inclusion** may result from poor welding technique, wrong electrode size or wrong electrode type.

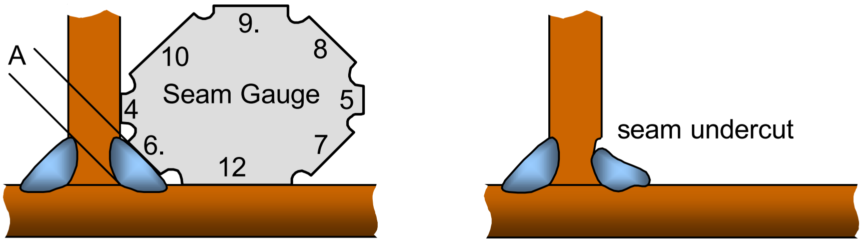


Figure 3.12: Checking of fillet seams

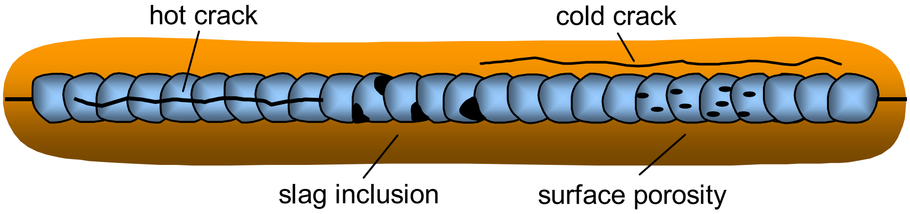


Figure 3.13: Seam faults

Crack detection may be enhanced by means of a crack detection kit, consisting of surface cleaning spray, dye penetration spray and dye developer spray.

If serious seam faults are detected, the responsible supercargo or port captain of BBC Chartering must be informed immediately and corrective steps taken as appropriate.

3.2.4 Timber shores

Timber shores are pressure elements for securing cargo and should therefore be fitted as tight as possible. However, due to drying and shrinking, a certain slack may develop during a sea passage, with the risk of disassembling of the shore construction. It is therefore essential to build a timber shore construction in principle as a "stand alone" unit fitting into the gap between cargo and ship or between cargo and cargo.

The actual shores should transfer the pressure load via timber cross-beams for spreading the load and avoiding damage to ship and cargo. These cross-beams must be suitably supported, e.g. by uprights of appropriate length. The cross-beams should have short overlaps at their ends. The shores themselves should rest on benches nailed to the uprights. The whole structure should be stabilised by diagonal braces.

The unsupported length of timber shores should be restricted to 2 metres due to the risk of buckling. If longer shores are needed, intermediate supports must be nailed on for stabilising against buckling.

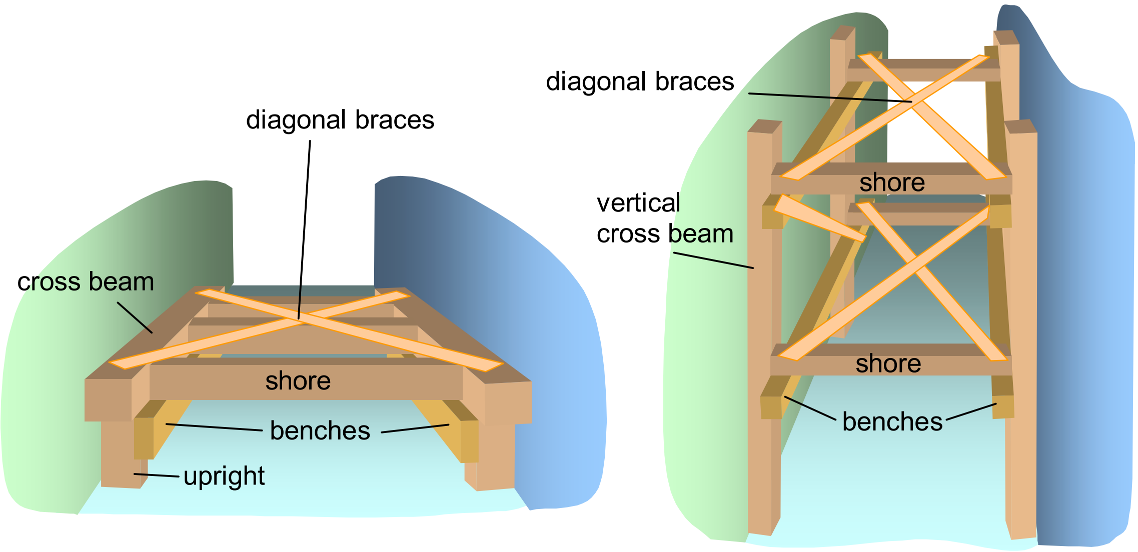


Figure 3.14: Timber shores with horizontal (left) and vertical cross beams (right)

3.2.5 *Anti-sliding mats*

Anti-sliding mats are available with a specified dynamic friction coefficient of 0.6, which is reduced to about 0.4 if surfaces become wet. The pressure resistance and shear resistance of anti-sliding mats is limited. Experience shows that such anti-sliding mats may only be used for heavy lifts, if the vertical static pressure does not exceed 3 to 4 bar, i.e. 30 to 40 t/m^2.

Calculated example:

A cargo unit of 150 t shall be loaded on the weather deck hatch cover on 4 pieces of 30 x 30 cm steel beams of 6.2 m length. The steel beams shall be bedded on anti-sliding mats over their full length, providing an area of $4 \cdot 6.2 \cdot 0.3 = 7.44$ m^2. Hence the load on the anti-sliding mats under the steel beams is 150/7.44 = 20.2 t/m^2 ≅ 2 bar, which is acceptable.

The cargo unit rests on the steel beams with two footprint beams of 0.25 m width at a right angle. The area of intersection of the foot prints and the beams is $8 \cdot 0.25 \cdot 0.3 = 0.6$ m^2. The pressure between the footprints and the beams is 150/0.6 = 250 t/m^2 ≅ 25 bar, which is too much for rubber mats. Therefore, hard wood planks must be used under the footprints.

3.3 Securing arrangements

3.3.1 *Principal layout*

A securing arrangement consists of an appropriate number of securing devices, which are arranged in accordance with the expected external forces. This means for simple sliding prevention that about 40% of the capacity of the securing devices should be directed each to port and starboard and 10% each to fore and aft. Additional securing devices may be needed for tipping prevention, but this is usually covered by the devices for sliding prevention. A final and more precise dimensioning of a securing arrangement may be obtained by checking the design, preferably with the "advanced calculation method" (CSS-Code, Annex 13).

Securing devices in the form of lashings should have a clear mission in terms of main securing purpose, i.e. securing to port or starboard or fore or aft.

The angle between the lashing direction and the deck level, the so-called vertical lashing angle α, should not exceed 60° for sliding prevention. It may be larger however, up to 90°, for tipping prevention.

The deviation of a lashing from its designated effective direction, the so-called horizontal lashing angle β, should not exceed 30°. If a horizontal angle exceeds this limit, the lashing should either be treated with reservation in the appropriate balance calculation or the so-called "alternative calculation method" (CSS-Code, Annex 13) should be used for assessing the arrangement, which accounts precisely for all horizontal lashing angles.

If transverse lashings have longitudinal components, these components should be evenly distributed to fore and aft, otherwise additional longitudinal securing devices must be applied as appropriate.

Lashings for transverse tipping prevention having vertical lashing angles $\alpha < 45°$ in combination with horizontal lashing angles $\beta > 45°$ should not be accounted for in the transverse tipping balance.

The risk of longitudinal tipping should be considered in the configuration of a securing arrangement, if high cargo units with a short longitudinal base are loaded.

3.3.2 Units without securing points

Cargo units without securing points may be secured by lashings, which envelope the whole unit in a suitable manner. Other options are setting welded stoppers or shoring with timber.

The method of pure down-strapping with the lashings guided over the unit and pre-tensioned simply for increasing the friction to the stowage place (**friction loop**) is inappropriate for heavy cargo units and must be banned.

Lashings turned around a cargo unit and tightened to both sides (**silly loop**) are inappropriate as well and misleading as they give the impression of having furnished independent lashings to both sides. They also must be banned for heavy cargo units.

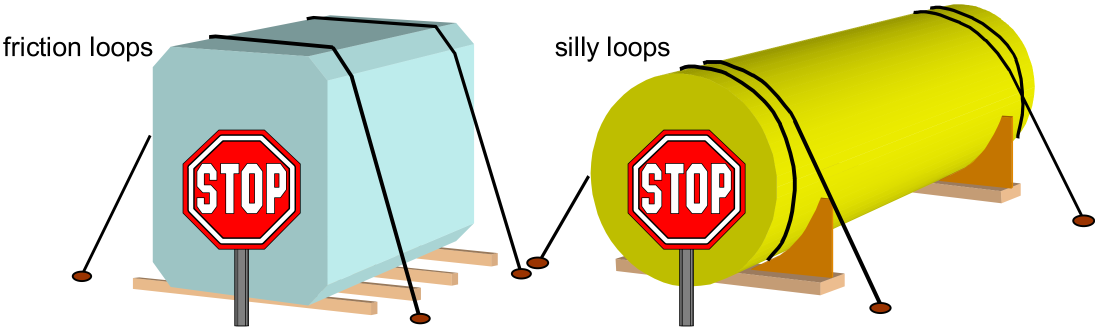


Figure 3.15: Examples of friction loops and silly loops

An appropriate and reliable way is the application of lashings going half way around a cargo unit with both ends tightened to the same side (**half loop**). These loops may be run horizontally or vertically around the cargo unit. Each end of a half loop counts as an independent lashing in a securing balance.

Grommets of an adapted size may be slipped over the head of cargo units (**head loop**), where they serve as a means to fasten direct lashings.

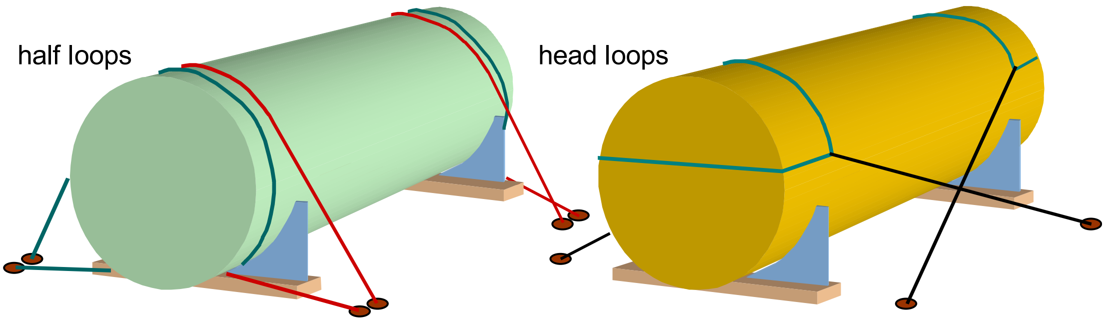


Figure 3.16: Examples of half loops and head loops

3.3.3 Homogeneity of securing arrangements

The securing arrangement for a particular cargo unit should be designed and implemented so that it is homogeneous in the following aspects:

- Securing devices are arranged symmetrically with regard to the centre of gravity of the cargo unit.
- Securing devices are aligned as close as possible to the intended direction of forces to be transferred.
- Securing devices have similar effective elasticity in order to carry their appropriate share of the external load to be compensated.

The "effective elasticity" of a securing device depends on cross-section, length, material modulus of elasticity and the specific deformation of that device, generated by the small movement of the cargo unit under the influence of external loads. A precise consideration of the effective elasticity of all securing devices is normally not within practical feasibility. However, some important conclusions may be drawn by carefully looking at the devices in a designed or implemented securing arrangement.

Example:

A **flexible cargo unit** is secured against transverse sliding by welded stopper plates and by lashings. The lashings are well pre-tensioned. Under the strain of an external force Fy the cargo unit is subject to a racking deformation. This deformation tensions the luff lashing, producing a restraining force, while the other lashing falls slack. Thus the flexibility of the cargo unit supports lashings and stoppers to share the total restraining load.

A **stiff cargo unit** with the same securing arrangement remains in shape under the external force Fy. There is no noteworthy elongation of the luff lashing regardless its pre-tension. Thus the stoppers must be able to take the total restraining load alone, while the lashings may be accountable for tipping prevention only.

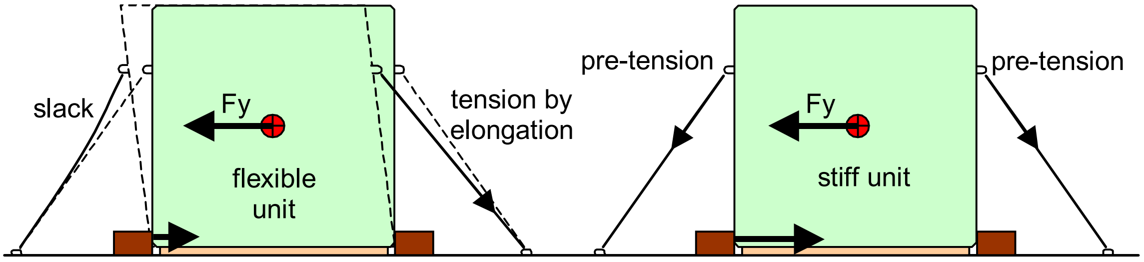


Figure 3.17: Homogeneity of securing arrangements

3.4 Assessment of securing arrangements

3.4.1 Visual inspection

The assessment of a securing arrangement requires a thorough visual inspection, in order to compare it with the planned lay-out, to check the technical performance and to collect final data for a balance calculation if deemed necessary. The following check-list may be beneficial for that purpose:

1. Is a bedding layer in place for improving friction (dunnage, plywood, square timber, anti-sliding mats)?
2. Are securing devices distinguishably positioned against transverse and longitudinal sliding?
3. Is there a risk of tipping and if so, are there suitable securing devices in place against transverse and longitudinal tipping?
4. In case of a tipping risk: Which levers a, b and c are applicable for the tipping balance according to the CSS-Code, Annex 13?
5. Which MSL-figures and lashing angles may be attributed to individual or groups of securing devices?
6. Are vertical angles of lashings against sliding not greater than 60°?
7. Are horizontal deviations of lashings against their designated effective direction not greater than 30°?
8. Is the whole securing arrangement homogeneous with regard to appropriate loading of securing devices?
9. Is the securing arrangement balanced with regard to the centre of gravity of the cargo unit?
10. Are conventional wire rope lashings assembled properly (rope arrangement, clips)?
11. Are all lashings given an appropriate pre-tension (long lashings intense, short lashings less)?
12. Have timber shoring arrangements been structured properly and secured against coming loose?
13. Have welded stoppers been placed according to the plan and welded properly?
14. Are all securing devices accessible during the sea passage?

3.4.2 IMO-Rule of Thumb

The wording of this rule in the Annex 13 to the IMO CSS-Code is:

The total of the MSL values of the securing devices on each side of a unit of cargo (port as well as starboard) should equal the weight of the unit.

This rule appears to apply a transverse acceleration of 1 g (9.81 m/s^2), where the cargo unit may effectively "hang" in the securing devices. However, the rule does not mention longitudinal securing. Thus a small part of the securing effort may be diverted into longitudinal securing. Furthermore, the rule does not specify the size of ship, her stability and speed, the location of stowage, the adverse effect of lashing angles nor the favourable effect of friction. In most cases therefore, the rule is considerably on the "safe side".

Yet, there are a number of restrictions mentioned in the Annex 13:

- Vertical lashing angles to the deck should not be greater than 60°.
- Adequate friction should be provided by the use of suitable material.
- Lashings at angles greater than 60° for tipping prevention should not be counted in the number of lashings under the rule of thumb.

The IMO-Rule of Thumb shall not be used for assessing the securing arrangement of cargo units with a mass greater than 30 t in ships operated by BBC Chartering.

3.4.3 Advanced calculation method

The advanced calculation method is a simplified approach of balancing transverse and longitudinal forces (sliding) and moments (tipping) by comparing external forces to the cargo with the restraint capacity of the securing arrangement. The load-deformation behaviour of securing devices is not taken into account. A certain non-homogeneous load distribution is compensated by an additional safety factor, namely by converting the MSL of securing devices into CS (calculated strength CS = MSL/1.5). Securing devices of same CS and direction may be combined in the calculation.

The method has basically been designed for manual calculation using a simple hand held computer. A form sheet for manual calculation is provided in the Annex to this Guideline.

3.4.4 Alternative calculation method

The alternative calculation method contains only minor changes to the advanced calculation method and shall not replace the latter. The changes in the alternative calculation method are:

- Horizontal lashing angles β accounted for by their real value.
- Calculation strength CS = MSL/1.35.
- Small changes in the balance calculation.

Horizontal lashing angles are the key issue of the improvement. This solves the frequent question on how to treat a lashing at, e.g. 45° to the transverse direction. However, the amount of entry data to the calculation is considerably increased and it is advisable to use an approved computer program for avoiding calculation errors within the processing of the lashing data.

The reduced safety factor achieved by applying CS = MSL/1.35 is a consequence to the more precise consideration of horizontal lashing angles.

The small changes in the balance calculation are insignificant, in particular if a computer program is used. The amended version 2002 of the Annex 13 contains a calculated example, which demonstrates that each lashing should be treated separately, duly distinguishing its direction of action (fore, aft, port, stbd). For each lashing two f-values must be taken from an appropriate table with the entries of the vertical and the horizontal lashing angle, and utilised within the applicable balance calculation.

The tipping balance in the alternative method is in fact identical with the one in the advanced method. It is furnished with a factor 0.9, which resets the reduced safety factor, so that the CS = MSL/1.35 may be used throughout the calculation.

3.4.5 Longitudinal tipping balance

Longitudinal tipping has not been described in the Annex 13, because it will be scarcely critical. However, large cargo units placed on deck may tip longitudinally and the appropriate securing arrangement should also be checked by a longitudinal tipping balance. In accordance with the balance of longitudinal sliding, which assumes a longitudinal force in conjunction with reduced weight of the cargo unit due to downward vertical acceleration of the ship, also the stabilising moment of the cargo unit should be reduced in the tipping balance. The balance therefore reads:

$$F_x \cdot a \leq b \cdot (m \cdot g - F_z) + \Sigma(CS_i \cdot c_i) \quad [kN \cdot m]$$

- Fx = longitudinal force [kN]
- Fz = vertical force [kN]
- a = longitudinal tipping lever [m]
- b = longitudinal lever of stableness [m]

- m = mass of cargo unit [t]
- g = gravity acceleration (9.81 m/s^2)
- CS_i = CS-values of longitudinal anti-tipping devices [kN]
- c_i = associated longitudinal anti-tipping levers [m]

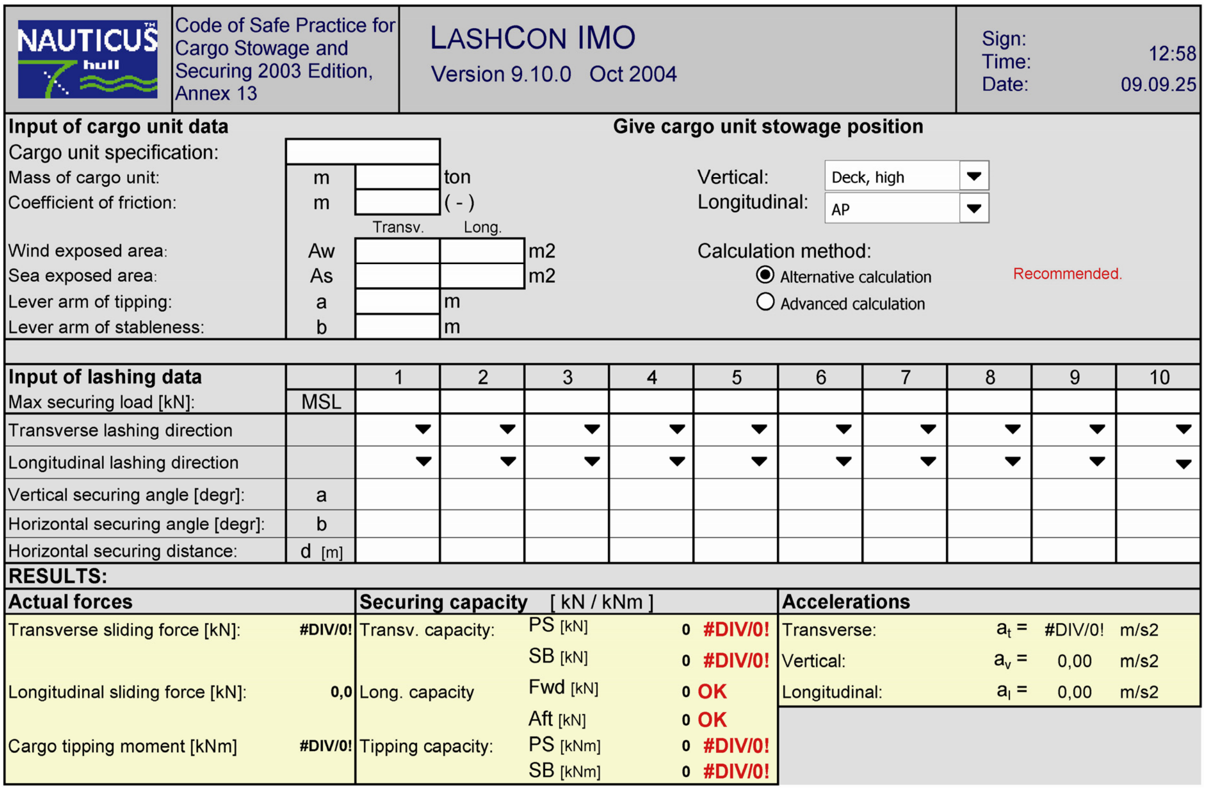
3.4.6 LashCon-calculation program

Among numerous suitable computer programs for the application of the advanced and the alternative calculation method, the most commonly used is the LashCon^{TM}, available from Det Norske Veritas through the internet.

The program offers a choice between the basic advanced calculation method and the alternative method with recommendation of the latter. It provides a storage stack for storing of calculated cases. It also offers print-outs of each page. The calculated accelerations may be replaced by figures adapted to conditions in sheltered waters.

However, there are several minor shortcomings, which must be overcome on occasion by manual calculation or by using LashCon in a multiple approach.

- The program does not allow the user to interpolate for entries of stowage levels. This may become particularly important for the stowage levels "on deck low" and "on deck high".
- The program does not allow the user to exclude steep transverse lashings from the transverse sliding balance, while using the same lashings for the transverse tipping balance.
- The program does not use tipping prevention levers "c", as proposed by the Annex 13. These levers are instead expressed by $c = d \cdot \sin\alpha$, where d is the horizontal distance from the tipping axis to the securing point on the deck level. This approach appears easier to handle but fails if the securing point is not on deck but higher, e.g. on the ship's side in the tween deck or lower hold.
- In the advanced method the program requires to enter a lashing a second time for checking the effect from its longitudinal component,
- The number of securing devices is limited to 10. Grouping of devices is therefore indispensable in larger securing arrangements. As grouping of lashings with the alternative method is not feasible in most cases, the given number of entry boxes is insufficient.



Code of Safe Practice for Cargo Stowage and Securing 2003 Edition, Annex 13

LASHCON IMO
Version 9.10.0 Oct 2004

Sign:
Time: 12:58
Date: 09.09.25

Input of cargo unit data

Cargo unit specification:				
Mass of cargo unit:	m		ton	
Coefficient of friction:	m		(-)	
		Transv.	Long.	
Wind exposed area:	Aw			m2
Sea exposed area:	As			m2
Lever arm of tipping:	a		m	
Lever arm of stableness:	b		m	

Give cargo unit stowage position

Vertical: Deck, high ▼
Longitudinal: AP ▼

Calculation method:
● Alternative calculation Recommended.
○ Advanced calculation

Input of lashing data		1	2	3	4	5	6	7	8	9	10
Max securing load [kN]:	MSL										
Transverse lashing direction		▼	▼	▼	▼	▼	▼	▼	▼	▼	▼
Longitudinal lashing direction		▼	▼	▼	▼	▼	▼	▼	▼	▼	▼
Vertical securing angle [degr]:	a										
Horizontal securing angle [degr]:	b										
Horizontal securing distance:	d [m]										

RESULTS:

Actual forces		**Securing capacity** [kN / kNm]			
Transverse sliding force [kN]:	#DIV/0!	Transv. capacity:	PS [kN]	0	#DIV/0!
			SB [kN]	0	#DIV/0!
Longitudinal sliding force [kN]:	0,0	Long. capacity	Fwd [kN]	0	OK
			Aft [kN]	0	OK
Cargo tipping moment [kNm]	#DIV/0!	Tipping capacity:	PS [kNm]	0	#DIV/0!
			SB [kNm]	0	#DIV/0!

Accelerations			
Transverse:	a_t =	#DIV/0!	m/s2
Vertical:	a_v =	0,00	m/s2
Longitudinal:	a_l =	0,00	m/s2

Figure 3.18: Working page of LashCon 9.1

3.4.7 Additional tipping moment

The tipping moment acting on a cargo unit in heavy weather, according to the Annex 13 calculation method, is simply derived from the nominal transverse or longitudinal force Fy or Fx, acting at the centre of gravity of the cargo unit, multiplied with the vertical distance of the force vector from a distinguished tipping axis. This approach is precise only for a cargo unit of the pin point size of its centre of gravity and sufficiently precise for cargo units of moderate dimensions, e.g. up to 10 m height and/or breadth in the plane of rotation.

For larger cargo units, the real distribution of mass and the inherent variation of distances from the rolling axis of the vessel creates an additional tipping moment, which should be taken into account when designing and implementing a securing arrangement.

This additional tipping moment results in fact from the rotational inertia of the cargo unit, when subjected to the rotational acceleration of a rolling or pitching vessel. It is independent from the vertical stowage position in the vessel, but will practically only appear with huge cargo units stowed on deck. It is obtained by the formula:

$$M_{add} = c \cdot m \cdot i_p^2 \ [kN \cdot m]$$

- M_{add} = additional tipping moment [kN·m]
- c = maximum angular acceleration of the vessel [s^{-2}]
- m = mass of the cargo unit [t]
- i_p = polar radius of inertia of the cargo unit [m]

The maximum angular acceleration is a function of the amplitude and the period of rolling or pitching of the vessel.

$$\text{For rolling: } c = \hat{\varphi} \cdot \left(\frac{2 \cdot \pi}{T_\varphi}\right)^2 \ [s^{-2}]\text{; for pitching: } c = \hat{\psi} \cdot \left(\frac{2 \cdot \pi}{T_\psi}\right)^2 \ [s^{-2}]$$

The period of large amplitude rolling may be estimated by the formula:

$$T_{\varphi} = \frac{0.78 \cdot B}{\sqrt{GM_C}} \text{ [s]}$$

B = breadth of the vessel [m]; GM_C = metacentric height, corrected for free surfaces [m]

The table below shows figures of c for various rolling periods and a roll amplitude ϕ = 30°.

T_{ϕ} [s]	8	9	10	11	12	13	14	15	16	17	18	20	24
c [s^{-2}]	0.32	0.26	0.21	0.17	0.14	0.12	0.11	0.09	0.08	0.07	0.06	0.05	0.04

The pitching period may be estimated using the vessel's length between perpendiculars:

$$T_{\psi} = 0.5 \cdot \sqrt{L_{PP}} \text{ [s]}$$

The table below shows figures of c for various pitching periods and an amplitude ψ = 12°.

T_{ψ} [s]	4	5	6	7	8
c [s^{-2}]	0.52	0.33	0.23	0.17	0.13

The polar radius of inertia of the cargo unit i_p depends on the cross-section of the cargo unit in the plane of tipping. There are several formulae available for estimating i_p.

If the mass of a square shaped unit is homogeneously distributed within the limits of length, width and height, then

$$i_p = \frac{1}{2} \cdot \sqrt{\frac{w^2 + h^2}{3}} = 0.289 \cdot \sqrt{w^2 + h^2} \text{ [m]}$$

If the mass of a square shaped unit is concentrated in the shell of the unit, i.e. the unit is a hollow body, then

$$i_p = \frac{w + h}{\sqrt{12}} = 0.289 \cdot (w + h) \text{ [m]}$$

If the mass of a cylindrical unit is homogeneously distributed within the limits of length and diameter d, then

$$i_p = \frac{d}{\sqrt{8}} = 0.354 \cdot d \text{ [m]}$$

If the mass of a cylindrical unit is concentrated in the shell of the unit, i.e. the unit is a hollow cylinder, then

$$i_p = \frac{d}{2} = 0.5 \cdot d \text{ [m]}$$

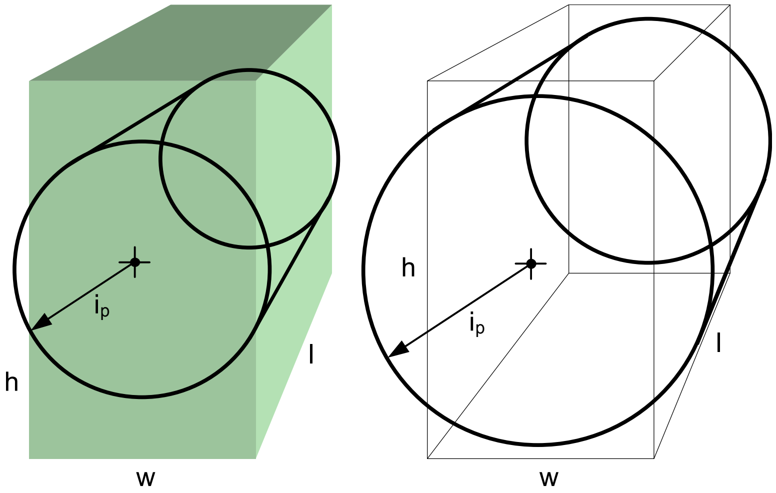


Figure 3.19: Polar radius of inertia i_p for a solid square shaped body (left) and a hollow square shaped body (right)

Example: A large RTG-unit of 130 t mass and dimensions l = 24 m, w = 12 m, h = 25 m shall be shipped in longitudinal position on deck high at 0.7 L of a vessel of Lpp = 113.5 m, B = 20.2 m, GM of 1.5 m and v_0 = 16 knots. The tipping lever a = 15 m. Estimated wind affected area is 302 m^2 transverse and 264 m^2 longitudinal.

Transverse tipping: The Annex 13 shows the following transverse force Fy.

$$Fy = 7.2 \cdot 0.98 \cdot 130 \; + \; 302 = 1219 \text{ kN}$$

The ordinary transverse tipping moment is 1219 · 15 = 18285 kN·m. The additional tipping moment is now calculated.

$$T_\varphi = \frac{0.78 \cdot 20.2}{\sqrt{1.5}} = 12.9 \text{ s}$$

$c = 0.12 \text{ s}^{-2}$ from the table above for $\phi = 30°$

i_p for a full body $= 0.289 \cdot \sqrt{12^2 + 25^2} = 8.0 \text{ m}$

i_p for a hollow body $= 0.289 \cdot (12 + 25) = 10.7 \text{ m}$

The RTG-unit appears to have most of its mass in the peripheral structure and equipment. Thus a figure of i_p = 10 m is chosen. Hence the additional tipping moment comes to:

$$M_{add} = 130 \cdot 0.12 \cdot 10^2 = 1560 \text{ kN·m}$$

The additional tipping moment amounts to about 8.5% of the ordinary tipping moment.

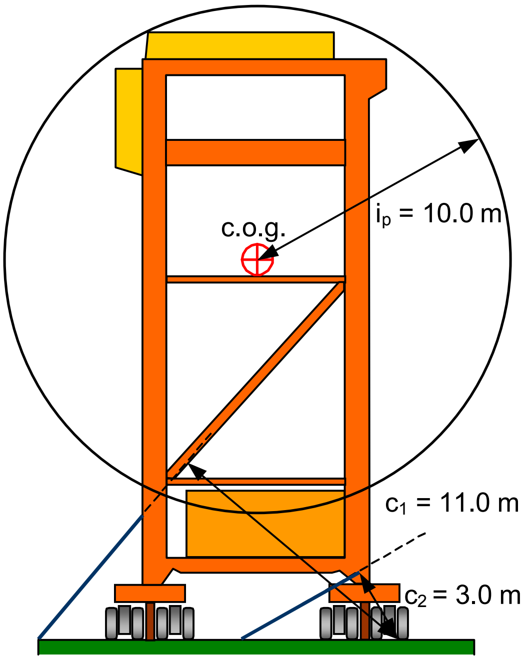


Figure 3.20: Transverse polar radius i_p

Longitudinal tipping:

The Annex 13 shows the following longitudinal force Fx.

$$Fx = 4.2 \cdot 0.98 \cdot 130 \; + \; 264 = 799 \text{ kN}$$

The ordinary longitudinal tipping moment is 799 · 15 = 11985 kN·m.

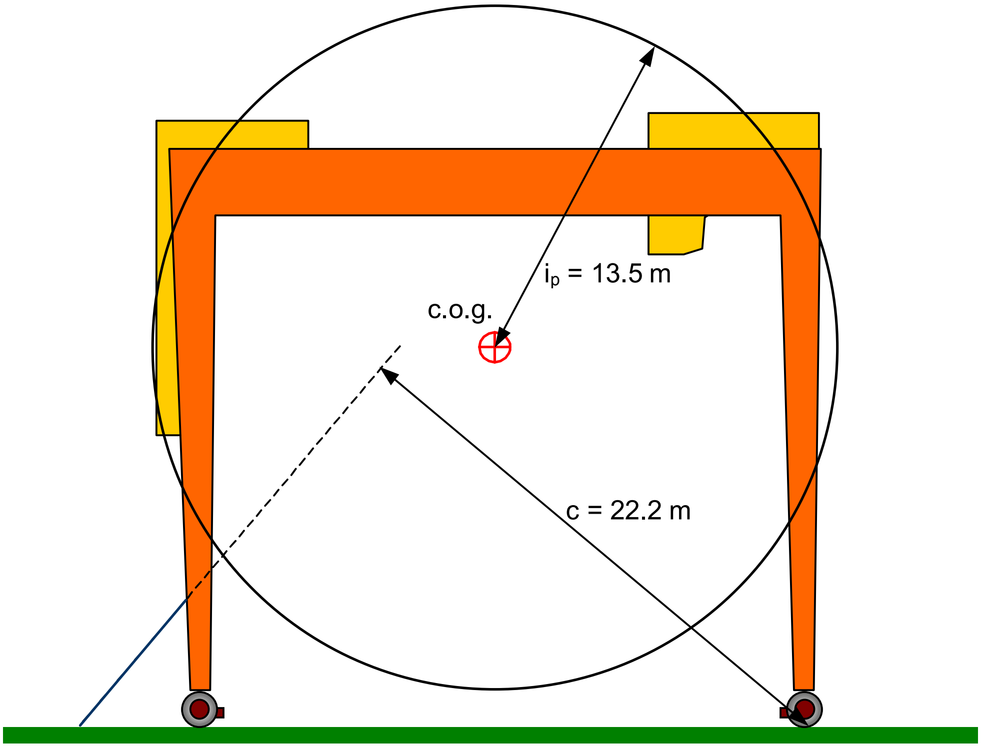


Figure 3.21: Longitudinal polar radius i_p

The additional tipping moment is now calculated.

$$T_\psi = 0.5 \cdot \sqrt{113.5} = 5.3 \text{ s}$$

c = 0.29 s^{-2} from the table above for ψ = 12°

i_p for a full body = $0.289 \cdot \sqrt{24^2 + 25^2}$ = 10.0 m

i_p for a hollow body = $0.289 \cdot (24 + 25)$ = 14.2 m

Again, a figure closer to the hollow body of i_p = 13.5 m is chosen. Hence the additional tipping moment comes to: $M_{add} = 130 \cdot 0.29 \cdot 13.5^2 = 6871$ kN·m

The additional tipping moment amounts to about 57% of the ordinary tipping moment. This is explainable by the greater radius of inertia and by the short pitching period, which creates a large rotational acceleration of the vessel.

3.4.8 Assessment example

The RTG described in the previous example is jacked up on eight steel sockets which are placed between each pair of wheels and welded to the steel plates under the bogies. The steel plates are fixed to the weather deck hatch covers by a sufficient number of plate stoppers with clip function. There is timber lining between the bogies and the steel sockets.

The securing devices consist of wire rope grommets, turnbuckles and shackles of minimum MSL = 150 kN. These lashings are arranged as shown in Figure 3.22. There are no stoppers or timber shores.

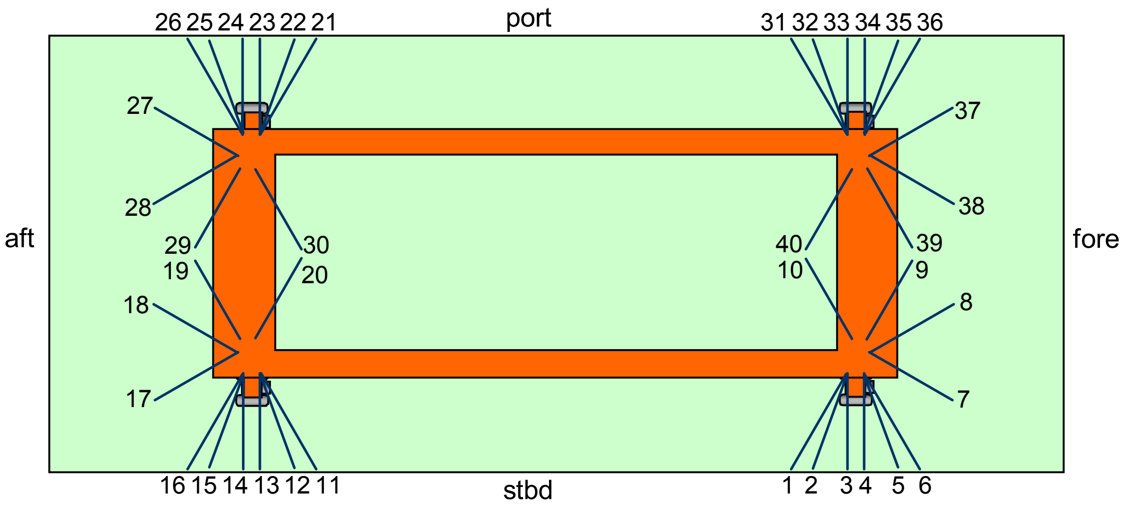


Figure 3.22: Lashing plan of example RTG

The assessment calculation is carried out by means of an attached form sheet. The figures of longitudinal and transverse acceleration have been extrapolated from the level "on deck high" in an arbitrary manner, due to the extreme height of the centre of gravity of the unit. It should be noted, that the stability of the vessel is not extreme in this case with GM = 1.5 m. An increase to only 2.0 m would enlarge the transverse forces and moments by about 20%.

The tipping moments are the critical parameters in this securing arrangement. This is escalated by the additional tipping moments, which have been considered in both the transverse and the longitudinal balance.

Due to the great variety of the horizontal lashing angles, the evaluation of the lashings has been carried out by means of the alternative calculation method in a separate form sheet. Each lashing has been individually numbered and evaluated for its effect in transverse and longitudinal direction. The results have been used in the assessment calculation sheet.

Assessment of securing arrangement according to IMO advanced calculation method

Ship: **BBC Asia**	Voy.No. **XYZ123**	Loading Port: **Anywhere**	
Cargo: **RTG**	Mass = **130** t	Dimensions: **25 x 12 x 24** m	
Lpp = **113.5** m	B = **20.2** m	Stowed in: **on deck X-high** at **0.7** Lpp	
GM = **1.5** m	v = **16.5** kn	Friction coeff. = **0.3**	Tipping lever a = **15** m
Corr.$_{length/speed}$ **0.98**	Corr.$_{B/GM}$ **1.00**	Lever b$_{transverse}$ **5.6** m	Lever b$_{longitudinal}$ **11.8** m

Fx =	**4.2 x 0.98 x 130 + 264 (windage area according to drawing)**	=	**799**	kN
Fy =	**7.2 x 0.98 x 130 + 302 (windage area according to drawing)**	=	**1219**	kN
Fz =	**6.2 x 0.98 x 130**	=	**790**	kN

Securing against sliding to port						Securing against sliding to stbd					
No	type of device	MSL	CS	α	f	No	type of device	MSL	CS	α	f
16	**wire rope lashings**	**150**	**111**			**16**	**wire rope lashings**	**150**	**111**		
	see alternative calc.						**see alternative calc.**				

Securing against sliding to fwd						Securing against sliding to aft					
No	type of device	MSL	CS	α	f	No	type of device	MSL	CS	α	f
4	**wire rope lashings**	**150**	**111**			**4**	**wire rope lashings**	**150**	**111**		
	see alternative calc.						**see alternative calc.**				

Securing against tipping to port					Securing against tipping to stbd				
No	type of device	MSL	CS	c	No	type of device	MSL	CS	c
12	**wire rope lashings**	**150**	**100**	**11.0**	**12**	**wire rope lashings**	**150**	**100**	**11.0**
4	**wire rope lashings**	**150**	**100**	**3.0**	**4**	**wire rope lashings**	**150**	**100**	**3.0**

Securing against tipping to fwd					Securing against tipping to aft				
No	type of device	MSL	CS	c	No	type of device	MSL	CS	c
6	**wire rope lashings**	**150**	**100**	**22.2**	**4**	**wire rope lashings**	**150**	**100**	**22.2**

Sliding to port:	**1219**	<	**0.3 x 130 x 9.81 + 1752 = 1969**	kN
Sliding to stbd:	**1219**	<	**0.3 x 130 x 9.81 + 1752 = 1969**	kN
Sliding to fwd:	**799**	<	**0.3 x (130 x 9.81 – 790) + 1156 = 1336**	kN
Sliding to aft:	**799**	<	**0.3 x (130 x 9.81 – 790) + 1156 = 1336**	kN
Tipping to port:	**18285 + 1560**	<	**5.6 x 130 x 9.81 + 13200 + 1200 = 21542**	kN·m
Tipping to stbd:	**18285 + 1560**	<	**5.6 x 130 x 9.81 + 13200 + 1200 = 21542**	kN·m
Tipping to fwd:	**11985 + 6871**	<	**11.8 x (130 x 9.81 – 790) + 13320 = 19047**	kN·m
Tipping to aft:	**11985 + 6871**	<	**11.8 x (130 x 9.81 – 790) + 13320 = 19047**	kN·m

Place and Date: ______________________ Name and Signature: ________________________

Evaluation of lashings by the alternative method (CS = MSL/1.35)

No	MSL	CS	α	s/p	β	f/a	fy	fx	CS·fy "s"	CS·fy "p"	CS·fy "f"	CS·fy "a"
1	150	111	50	s	30	a	0.79	0.55	88			61
2	150	111	50	s	20	a	0.83	0.45	92			50
3	150	111	50	s	0	a	0.87	0.23	97			26
4	150	111	50	s	0	f	0.87	0.23	97		26	
5	150	111	50	s	20	f	0.83	0.45	92		50	
6	150	111	50	s	30	f	0.79	0.55	88		61	
7	150	111	50	s	60	f	0.55	0.79	61		88	
8	150	111	50	p	60	f	0.55	0.79		61	88	
9	150	111	30	p	30	f	0.90	0.58		100	64	
10	150	111	30	p	30	a	0.90	0.58		100		64
11	150	111	50	s	30	f	0.79	0.55	88		61	
12	150	111	50	s	20	f	0.83	0.45	92		50	
13	150	111	50	s	0	f	0.87	0.23	97		26	
14	150	111	50	s	0	a	0.87	0.23	97			26
15	150	111	50	s	20	a	0.83	0.45	92			50
16	150	111	50	s	30	a	0.79	0.55	88			61
17	150	111	50	s	60	a	0.55	0.79	61			88
18	150	111	50	p	60	a	0.55	0.79		61		88
19	150	111	30	p	30	a	0.90	0.58		100		64
20	150	111	30	p	30	f	0.90	0.58		100	64	
21	150	111	50	p	30	f	0.79	0.55		88	61	
22	150	111	50	p	20	f	0.83	0.45		92	50	
23	150	111	50	p	0	f	0.87	0.23		97	26	
24	150	111	50	p	0	a	0.87	0.23		97		26
25	150	111	50	p	20	a	0.83	0.45		92		50
26	150	111	50	p	30	a	0.79	0.55		88		61
27	150	111	50	p	60	a	0.55	0.79		61		88
28	150	111	50	s	60	a	0.55	0.79	61			88
29	150	111	30	s	30	a	0.90	0.58	100			64
30	150	111	30	s	30	f	0.90	0.58	100		64	
31	150	111	50	p	30	a	0.79	0.55		88		61
32	150	111	50	p	20	a	0.83	0.45		92		50
33	150	111	50	p	0	a	0.87	0.23		97		26
34	150	111	50	p	0	f	0.87	0.23		97	26	
35	150	111	50	p	20	f	0.83	0.45		92	50	
36	150	111	50	p	30	f	0.79	0.55		88	61	
37	150	111	50	p	60	f	0.55	0.79		61	88	
38	150	111	50	s	60	f	0.55	0.79	61		88	
39	150	111	30	s	30	f	0.90	0.58	100		64	
40	150	111	30	s	30	a	0.90	0.58	100			64
								Total:	1752	1752	1156	1156

Glossary

Item	Location of reference and explanation
additional tipping moment	see Chapter 3.4.7
advanced calculation method	see Chapter 3.4.3
alternative calculation method	see Chapter 3.4.4
angle stopper	see Chapter 3.2.3
anti-sliding mats	see Chapter 3.2.5
beam theory	see Chapter 2.1.2
bending moment	see Chapter 2.1.2
butt seam	see Figure 3.6
calculated strength	see Chapter 3.4.3
centre of gravity	(c.o.g.) center of gravity of a system of partial masses is the substitutional position of the same mass of pin-point size
centre of suspension	see Chapter 1.2.6; usually the centre of the hook-bolt
chain lashings	see Chapter 3.2.1
compacting	see Chapter 3.1.2
compression spreader	see Chapter 1.2.8; spreader for forcing slings apart; additional spreader support wires required
connecting beam	see Chapters 1.1.4 and 1.2.3
direct securing	see Chapter 3.1.2
down-strapping	see Chapter 3.1.2
effective forces	see Chapter 1.2.7; forces exceeding the hanging forces
effective length of beam	see Chapter 2.2.3 and table, applicable for Condition A only
effective length of shackle	see Figure 1.10
fibre rope grommet	see Chapter 1.1.2
fillet seam	see Figure 3.6
foot print area	see Chapter 2.1.1; areas of cargo contact to the stowage place
friction loop	see Chapter 3.3.2
geometrical centre	mid between outer dimensions of a cargo unit
gross length of sling	see Figure 1.10
half loop	see Chapter 3.3.2
hanging force	see Chapter 1.2.7; vertical force to a lifting point on the cargo
H-beam stopper	see Chapter 3.2.3
head loop	see Chapter 3.3.2
heeling angle	see Chapter 1.4.1; list of the ship
high tensile steel	low alloy steel having an upper yield strength in excess of 235 N/mm^2; usual applications: S 275 and S 355
hoist	lifting tackle
hoisting angle	see Chapter 1.4.1; deviation of the crane hoist from the vertical
hoisting distance	see Figure 1.8
homogeneous securing arrangement	see Chapter 3.3.3
horizontal lashing angle β	see Chapter 3.3.1
instability	see Chapter 1.2.6, if applicable to a suspension arrangement
inverse proportionality	see Figure 1.13; relation of hanging forces to position of c.o.g.
lifting beam	see Chapter 1.1.4; beam has connecting points for primary slings to the hook and secondary slings to the cargo unit
lifting brackets	devices on a cargo unit for attaching slings or shackles for lifting
lifting lugs	devices on a cargo unit for attaching slings or shackles for lifting
lifting points	devices on a cargo unit for attaching slings or shackles for lifting

lifting shackle	see Chapter 1.1.3
load spreading	see Chapter 2.1.1
load transferring	see Chapter 2.1.1
luffing angle	see chapter 1.4.1; vertical angle of crane boom
maximum securing load	(MSL); see Chapter 3.2
metacentre	intersection of buoyancy vectors at small angles of heel
net length of sling	see Figure 1.10
offset	position of centre of gravity in an unsymmetrical situation
outreach of crane	see Chapter 1.3.2
permissible area load	(PAL); see Chapter 2.1.1
permissible tensile stress	see Chapters 2.2.1 and 2.2.2
plate stopper	see Chapter 3.2.3
point load	see Chapter 2.1.3 and Figure 2.2
primary suspension	see Chapter 1.2.6; connection to the cargo hook
safe working load	(SWL) load limit in a lifting device that must not be exceeded
safety factor	see Chapter 1.1.5
secondary suspension	see Chapter 1.2.6; connection to the traverse or beam
section modulus	see Chapters 2.2.1 and 2.2.2
securing arrangement	suitable combination of securing devices for fastening a cargo unit to the stowage place on board the ship
securing device	lashing, shore, stopper, lock
securing element	single piece of securing equipment, e.g. shackle, turnbuckle etc.
shear force	see Chapter 2.1.2
silly loop	see Chapter 3.3.2
slinging height	see Figure 1.8
SMS-Manual	Safety Management Manual according to the ISM-Code
spreader support wires	see Chapter 1.2.8
stability pontoon	see Chapter 1.3.4
statically determinate	see Chapter 1.2.7; hanging forces may be clearly determined
suspension angle	see Figure 1.16
suspension arrangement	suitable combination of lifting devices for hanging a cargo unit to the hook(s) of the crane(s)
timber shores	see Chapter 3.2.4
twin beams	see Figure 2.7
vertical lashing angle α	see Chapter 3.3.1
web lashings	see Chapter 3.2.1
welding faults	see Chapter 3.2.3
wire belt sling	flat wire rope belt with special shackles, used for lifting
wire rope grommet	see Chapter 1.1.1
wire rope lashings	see Chapter 3.2.1; types A, B, C and "La Paloma"
wire rope sling	see Chapter 1.1.1
working load limit	(WLL) load limit in a lifting device that must not be exceeded
working radius	see Figure 1.19

Annex

- Form sheet for completing the advanced calculation method.
- Form sheet for the evaluation of lashings by the alternative calculation method.

Assessment of securing arrangement according to IMO advanced calculation method

Ship:	Voy.No.	Loading Port:	
Cargo:	Mass = t	Dimensions: m	
Lpp = m	B = m	Stowed in: at Lpp	
GM = m	v = kn	Friction coeff. =	Tipping lever a = m
Corr.$_{\text{length/speed}}$	Corr.$_{\text{B/GM}}$	Lever $b_{\text{transverse}}$ m	Lever $b_{\text{longitudinal}}$ m

Fx =	=	kN
Fy =	=	kN
Fz =	=	kN

Securing against sliding to port						Securing against sliding to stbd					
No	type of device	MSL	CS	α	f	No	type of device	MSL	CS	α	f

Securing against sliding to fwd						Securing against sliding to aft					
No	type of device	MSL	CS	α	f	No	type of device	MSL	CS	α	f

Securing against tipping to port					Securing against tipping to stbd				
No	type of device	MSL	CS	c	No	type of device	MSL	CS	c

Securing against tipping to fwd					Securing against tipping to aft				
No	type of device	MSL	CS	c	No	type of device	MSL	CS	c

Sliding to port:	<	kN
Sliding to stbd:	<	kN
Sliding to fwd:	<	kN
Sliding to aft:	<	kN
Tipping to port:	<	kN·m
Tipping to stbd:	<	kN·m
Tipping to fwd:	<	kN·m
Tipping to aft:	<	kN·m

Place and Date: ____________________________ Name and Signature: ______________________________

Evaluation of lashings by the alternative method (CS = MSL/1.35)

No	MSL	CS	α	s/p	β	f/a	fy	fx	CS·fy "s"	CS·fy "p"	CS·fy "f"	CS·fy "a"
								Total:				

Notes