2 Packing and securing materials

2.1 Dunnaging and separating material

2.1.1 Dunnaging materials should be used as appropriate for the protection of the cargo against water from condensed humidity, in particular by:

- Timber planks against water collecting at the bottom of the CTU;
- Gunny cloth, paperboard or natural fibre mats against water dropping from the ceiling; and
- Timber planks or plywood against sweat water running down the sides of the CTU.

2.1.2 Timber planks or scantlings may also be used for creating gaps between parcels of cargo in order to facilitate natural ventilation, particularly in ventilated containers. Moreover, the use of such dunnaging is indispensable, when packing reefer containers.

2.1.3 Timber planks, plywood sheets or pallets may be used to equalize loads within stacks of cargo parcels and to stabilize these stacks against dislocation or collapse. The same material may be used for separating packages, which may damage each other or even for installing a temporary floor in a CTU for eliminating inappropriate stack loads to the cargo (see figure 7.2).

Figure 7.2 Timber temporary floor

2.1.4 Cardboard or plastic sheathing may be used for protecting sensitive cargo from dirt, dust or moisture, in particular while packing is still in progress.

2.1.5 Dunnaging material, in particular sheets of plastic or paper and fibre nets may be used for separating unpackaged cargo items, which are designated for different consignees.

2.1.6 The restrictions on the use of dunnaging materials with regard to quarantine regulations, in particular wood or timber, should be kept in mind (see sections 1.13 and 1.14 of this annex).

2.2 Friction and friction increasing material

2.2.1 For handling and packing of cartons and pushing heavy units a low friction surface may be desirable. However, for minimizing additional securing effort, a high friction between the cargo and the stowage ground of the CTU is of great advantage. Additionally, good friction between parcels or within the goods themselves, e.g. powder or granulate material in bags, will support a stable stow.

2.2.2 The magnitude of the vertical friction forces between a cargo item and the stowage ground depends on the mass of the item, the vertical acceleration coefficient and a specific friction factor μ, which may be obtained from appendix 2 to this annex.

Friction force:

$$F_F = \mu \cdot c_z \cdot m \cdot g \quad [\text{kN}], \qquad \text{with mass of cargo [t] and } g = 9.81\ [\text{m/s}^2]$$

2.2.2.1 The factors presented in appendix 2 are applicable for static friction between different surface materials. These figures may be used for cargoes secured by blocking or by friction lashings.

2.2.2.2 For cargoes secured by direct securing, a dynamic friction factor should be used with 75% of the applicable static friction factor, because the necessary elongation of the lashings for attaining the desired restraint forces will go along with a little movement of the cargo.

2.2.2.3 The friction values given in appendix 2 to this annex are valid for swept clean dry or wet surfaces free from frost, ice, snow, oil and grease. When a combination of contact surfaces is missing in the table in appendix 2 or if the friction factor cannot be verified in another way, the maximum friction factor to be used in calculations is 0.3. If the surface contact is not swept clean, the maximum friction factor to be used is 0.3 or the value in the table, when this is lower. If the surface contacts are not free from frost, ice and snow a friction factor $\mu = 0.2$ should be used unless the table shows a lower value. For oily and greasy surfaces or when slip sheets have been used a friction factor $\mu = 0.1$ should be used. The friction factor for a material contact can be verified by static inclination or dragging tests. A number of tests should be performed to establish the friction for a material contact (see appendix 3 to this annex).

2.2.3 Friction increasing materials like rubber mats, sheets of structured plastics or special cardboard may provide considerably higher friction factors, which are declared and certified by the manufacturers. However, care should be taken in the practical use of these materials. Their certified friction factor may be limited to perfect cleanliness and evenness of the contact areas and to specified ambient conditions of temperature and humidity. The desired friction increasing effect will be obtained only if the weight of the cargo is fully transferred via the friction increasing material, this means only if there is no direct contact between the cargo and the stowage ground. Manufacturer's instructions on the use of the material should be observed.

2.3 Blocking and bracing material and arrangements

2.3.1 Blocking, bracing or shoring is a securing method, where e.g. timber beams and frames, empty pallets or dunnage bags are filled into gaps between cargo and solid boundaries of the CTU or into gaps between different packages (see figure 7.3). Forces are transferred in this method by compression with minimal deformation. Inclined bracing or shoring arrangements bear the risk of bursting open under load and should therefore be properly designed. In CTUs with strong sides, if possible, packages should be stowed tightly to the boundaries of the CTU on both sides, leaving the remaining gap in the middle. This reduces the forces to the bracing arrangement, because lateral g-forces from only one side will need to be transferred at a time.

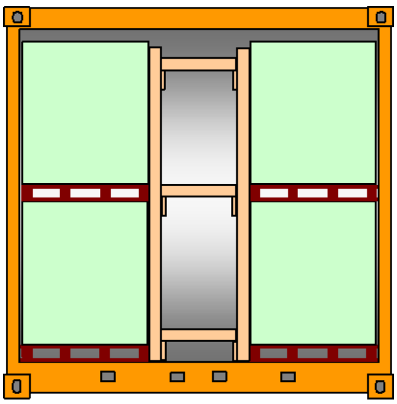

Figure 7.3 Centre gap with transverse bracing

2.3.2 Forces being transferred by bracing or shoring need to be dispersed at the points of contact by suitable cross-beams, unless a point of contact represents a strong structural member of the cargo or the CTU. Softwood timber cross-beams should be given sufficient overlaps at the shore contact points. For the assessment of bedding and blocking arrangements, the nominal strength of timber should be taken from the following table:

	Compressive strength normal to the grain	**Compressive strength parallel to the grain**	**Bending strength**
Low quality	0.3 kN/cm²	2.0 kN/cm²	2.4 kN/cm²
Medium quality	0.5 kN/cm²	2.0 kN/cm²	3.0 kN/cm²

2.3.3 A bracing or shoring arrangement should be designed and completed in such a way that it remains intact and in place, also if compression is temporarily lost. This requires suitable uprights or benches supporting the actual shores, a proper joining of the elements by nails or clamps and the stabilizing of the arrangement by diagonal braces as appropriate (see figures 7.4 and 7.5).

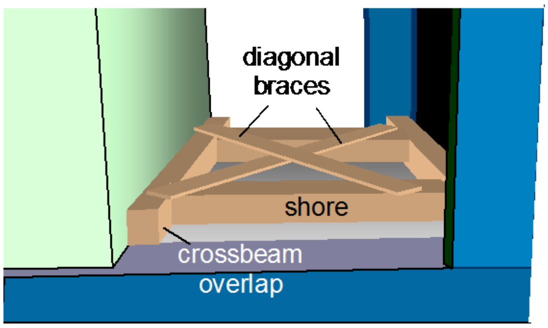

Figure 7.4 Shoring arrangement showing cross beam overlap and diagonal braces

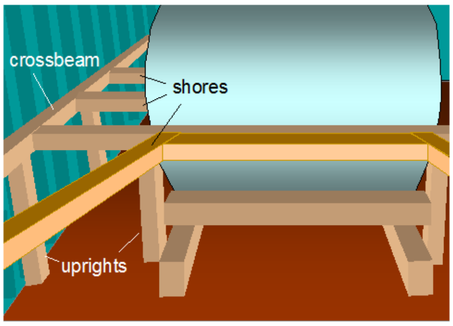

Figure 7.5 Shoring arrangement with uprights and crossbeam

2.3.4 Transverse battens in a CTU, intended to restrain a block of packages in front of the door or at intermediate positions within the CTU, should be sufficiently dimensioned in their cross section, in order to withstand the expected longitudinal forces from the cargo (see figure 7.6). The ends of such battens may be forced into solid corrugations of the side walls of the CTU. However, preference should be given to brace them against the frame structure, such as bottom or top rails or corner posts. Such battens act as beams, which are fixed at their ends and loaded homogeneously over their entire length of about 2.4 metres. Their bending strength is decisive for the force that can be resisted. The required number of such battens together with their dimensions may be identified by calculations, which is shown in appendix 4 to this annex.

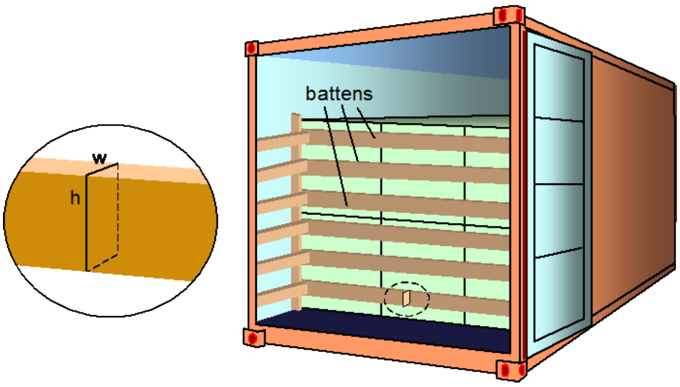

Figure 7.6 General layout of fence battens for door protection in a CTU

2.3.5 Blocking by nailed on scantlings should be used for minor securing demands only. Depending on the size of the nails used, the shear strength of such a blocking arrangement may be estimated to take up a blocking force between 1 and 4 kN per nail. Nailed on wedges may be favourable for blocking round shapes like pipes. Care should be taken that wedges are cut in a way that the direction of grain supports the shear strength of the wedge. Any such timber battens or wedges should only be nailed to dunnage or timbers placed under the cargo. Wooden floors of closed CTUs are generally not suitable for nailing. Nailing to the softwood flooring of flatracks or platforms and open CTUs may be acceptable with the consent of the CTU operator (see figure 7.7).

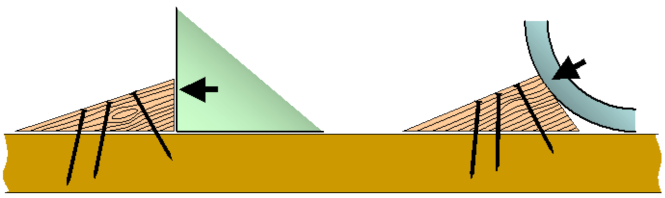

Figure 7.7 Properly cut and nailed wedges

2.3.6 In the case of form locking, void spaces should be filled and may be favourably stuffed by empty pallets inserted vertically and tightened by additional timber battens as necessary. Material which may deform or shrink permanently, like rags of gunny cloth or solid foam of limited strength, should not be used for this purpose. Small gaps between unit loads and similar cargo items, which cannot be avoided and which are necessary for the smooth packing and unpacking of the goods, are acceptable and need not to be filled. The sum of void spaces in any horizontal direction should not exceed 15 cm. However, between dense and rigid cargo items, such as steel, concrete or stone, void spaces should be further minimized, as far as possible.

2.3.7 Gaps between cargo that is stowed on and firmly secured to pallets (by lashings or by shrink foil), need not to be filled, if the pallets are stowed tightly into a CTU and are not liable to tipping (see figure 7.8). Securing of cargo to pallets by shrink foil wrapping is only sufficient if the strength of the foil is appropriate for above purpose. It should be considered that in case of sea transport repetitive high loadings during bad weather may fatigue the strength of a shrink foil and thereby reduce the securing capacity.

Figure 7.8 Cargo firmly secured to pallets by textile lashings

2.3.8 If dunnage bags are used for filling gaps[2], the manufacturer's instructions on filling pressure and the maximum gap should be accurately observed. Dunnage bags should not be used as a means of filling the space at the doorway, unless precautions are taken to ensure that they cannot cause the door to open violently when the doors are opened. If the surfaces in the gap are uneven with the risk of damage to the dunnage bags by chafing or piercing, suitable measures should be taken for smoothing the surfaces appropriately (see figures 7.9 and 7.10). The blocking capacity of dunnage bags should be estimated by multiplying the nominal burst pressure with the contact area to one side of the blocking arrangement and with a safety factor of 0.75 for single use dunnage bags and 0.5 for reusable dunnage bags (see appendix 4 to this annex).

Figure 7.9 Gap filled with a central dunnage bag

Figure 7.10 Irregular shaped packages blocked with dunnage bags

2.3.9 The restrictions on the use of blocking and bracing materials with regard to quarantine regulations, in particular for wood or timber, should be kept in mind (see sections 1.13 and 1.14 of this annex).

2 Dunnage bags (inflated by air) should not be used for dangerous goods on US railways.

2.4 Lashing materials and arrangements

2.4.1 Lashings transfer tensile forces. The strength of a lashing may be declared by its breaking strength or breaking load (BL). The maximum securing load (MSL) is a specified proportion of the breaking strength and denotes the force that should not be exceeded in securing service. The term lashing capacity (LC), used in national and regional standards, corresponds to the MSL. Values for BL, MSL or LC are indicated in units of force, i.e. kilonewton (kN) or dekanewton (daN).

2.4.2 The relation between MSL and the breaking strength is shown in the table below. The figures are consistent with Annex 13 of the IMO Code of Safe Practice for Cargo Stowage and Securing. Corresponding relations according to standards may differ slightly.

Material	MSL
shackles, rings, deck eyes, turnbuckles of mild steel	50% of breaking strength
fibre ropes	33% of breaking strength
web lashings (single use)	75% of breaking strength[1]
web lashings (reusable)	50% of breaking strength
wire ropes (single use)	80% of breaking strength
wire ropes (reusable)	30% of breaking strength
steel band (single use)	70% of breaking strength[2]
chains	50% of breaking strength
[1] Maximum allowed elongation 9% at MSL.	
[2] It is recommended to use 50%.	

2.4.3 The values of MSL quoted in the table above rely on the material passing over smooth or smoothed edges. Sharp edges and corners will substantially reduce these values. Wherever possible or practicable, appropriate edge protectors should be used (see figures 7.11 and 7.12).

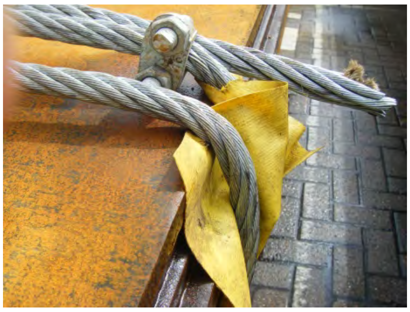

Figure 7.11 Poor edge protection

Figure 7.12 Edge protectors

2.4.4 Lashings transfer forces under a certain elastic elongation only. They act like a spring. If loaded more than the specific MSL, elongation may become permanent and the lashing will fall slack. New wire and fibre ropes or lashings may show some permanent elongation until gaining the desired elasticity after repeated re-tensioning. Lashings should be given a pre-tension, in order to minimize cargo movement. However, the initial pre-tension should never exceed 50% of the MSL.

2.4.5 Fibre ropes of the materials manila, hemp, sisal or manila-sisal-mix and moreover synthetic fibre ropes may be used for lashing purposes. If their MSL is not supplied by the manufacturer or chandler, rules of thumb may be used for estimating the MSL with d = rope diameter in cm:

Natural fibre ropes: $MSL = 2 \cdot d^2$ [kN]
Polypropylene ropes: $MSL = 4 \cdot d^2$ [kN]
Polyester ropes: $MSL = 5 \cdot d^2$ [kN]
Polyamide ropes: $MSL = 7 \cdot d^2$ [kN]

Composite ropes made of synthetic fibre and integrated soft wire strings provide suitable stiffness for handling, knotting and tightening and less elongation under load. The strength of this rope is only marginally greater than that made of plain synthetic fibre.

2.4.6 There is no strength reduction to fibre ropes due to bends at round corners. Rope lashings should be attached as double, triple or fourfold strings and tensioned by means of wooden turn sticks. Knots should be of a professional type, e.g. bowline knot and double half hitch[3]. Fibre ropes are highly sensitive against chafing at sharp corners or obstructions.

2.4.7 Web lashings may be reusable devices with integrated ratchet tensioner or one-way hardware, available with removable tensioning and lockable devices. The permitted securing load is generally labelled and certified as lashing capacity LC. There is no rule of thumb available for estimating the MSL due to different base materials and fabrication qualities. The fastening of web lashings by means of knots reduces their strength considerably and should therefore not be applied.

2.4.8 The elastic elongation of web lashings, when loaded to their specific MSL should not exceed 9%. Web lashings should be protected against chafing at sharp corners, against mechanical wear and tear in general and against chemical agents like solvents, acids and others.

2.4.9 Wire rope used for lashing purposes in CTUs for sea transport consists of steel wires with a nominal BL of around 1.6 kN/mm^2 and the favourite construction 6 x 19 + 1FC, i.e. 6 strands of 19 wires and 1 fibre core (see figure 7.13). If a certified figure of MSL is not available, the MSL for one-way use may be estimated by $MSL = 40 \cdot d^2$ [kN]. Other available lashing wire constructions with a greater number of fibre cores and less metallic cross section have a considerably lesser strength related to the outer diameter. The elastic elongation of a lashing wire rope is about 1.6% when loaded to one-way MSL, but an initial permanent elongation should be expected after the first tensioning, if the wire rope is new.

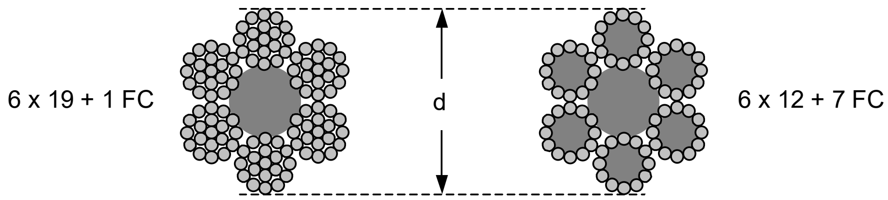

Figure 7.13 Typical lashing wire rope construction

2.4.10 Narrow rounded bends reduce the strength of wire ropes considerably. The residual strength of each part of the rope at the bend depends on the ratio of bend diameter to the rope diameter as shown in the table below.

ratio: bend diameter/rope diameter	1	2	3	4	5
residual strength with rope steady in the bend	65%	76%	85%	93%	100%

Bending a wire rope around sharp corners, like passing it through the edged hole of an eye-plate, reduces its strength even more. The residual MSL after a 180° turn through such an eye-plate is only about 25% of the MSL of the plain rope, if steady in the bend.

3 Knots will reduce the strength of the rope.

2.4.11 Wire rope lashings in sea transport are usually assembled by means of wire rope clips. It is of utmost importance that these clips are of appropriate size and applied in correct number, direction and tightness. Recommended types of such wire rope lashing assemblies are shown in figure 7.14. A typical improper assembly is shown in figure 7.15.

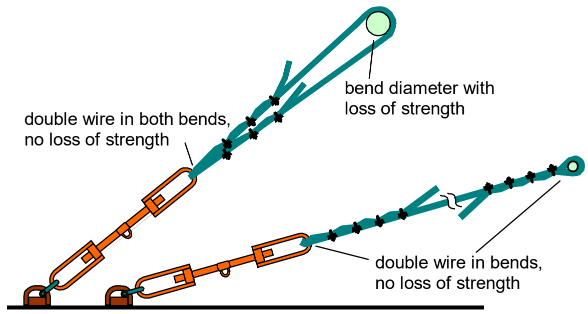

Figure 7.14 Recommended assemblies for wire rope lashing

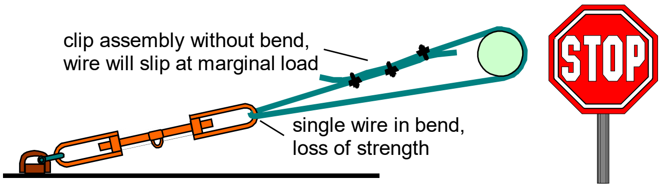

Figure 7.15 Improper assembly for wire rope lashing

2.4.12 Tensioning and joining devices associated with wire rope lashings in sea transport are generally not standardized. The MSL of turnbuckles and lashing shackles should be specified and documented by the manufacturer and at least match the MSL of the wire rope part of the lashing. If manufacturer information is not available, the MSL of turnbuckles and shackles made of ordinary mild steel may be estimated by $MSL = 10 \cdot d^2$ [kN] with d = diameter of thread of turnbuckle or shackle bolt in cm.

2.4.13 Wire rope lashings in road transport are specified as reusable material of distinguished strength in terms of lashing capacity (LC), which should be taken as MSL. Connections elements like shackles, hooks, thimbles, tensioning devices or tension indicators are accordingly standardized by design and strength. The use of wire rope clips for forming soft eyes has not been envisaged. Assembled lashing devices are supplied with a label containing identification and strength data (see figure 7.16). When using such material, the manufacturer's instructions should be observed.

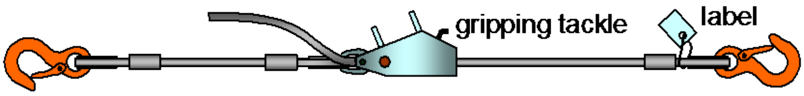

Figure 7.16 Standard wire lashing used in road transport with gripping tackle

2.4.14 Lashing chains used in sea transport are generally long link chains of grade 8 steel. A 13 mm chain of grade 8 steel has a MSL of 100 kN. The MSL for other dimensions and steel qualities should be obtained from the manufacturer's specification. The elastic elongation of the above long link chains is about 1% when loaded to their MSL. Long link chains are sensitive against guiding them around bends of less than about 10 cm radius. The favourite tensioning device is a lever with a so-called climbing hook for re-tightening the lashing during service (see figure 7.17). Manufacturer's instructions and, when existing, national regulations on the use of the tensioning lever and re-tensioning under load should be strictly observed.

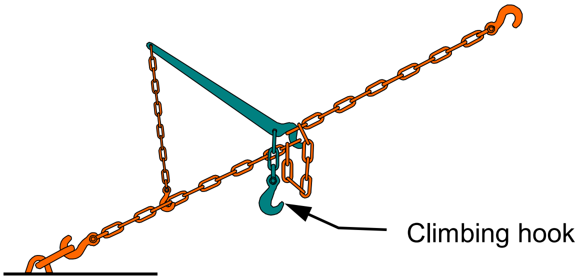

Figure 7.17 Long link lashing chain with lever tensioner

2.4.15 Chain lashings used in road and rail transport according to European standards are mainly short link chains. Long link chains are generally reserved for the transport of logs. Short link chains have an elastic elongation of about 1.5%, when loaded to their MSL. The standard includes various systems of tensioners, specially adapted hooks, damping devices and devices to shorten a chain to the desired loaded length. Chain compound assemblies may be supplied with a label containing identification and strength data (see figure 7.18). Manufacturer's instructions on the use of the equipment should be strictly observed.

Figure 7.18 Standard chain lashing with shortening hook

2.4.16 Steel band for securing purposes is generally made of high tension steel with a normal breaking strength of 0.8 to 1.0 kN/mm^2. Steel bands are most commonly used for unitizing packages to form greater blocks of cargo (see figure 7.19). In sea transport, such steel bands are also used to "tie down" packages to flatracks, platforms or roll-trailers. The bands are tensioned and locked by special manual or pneumatic tools. Subsequent re-tensioning is not possible. The low flexibility of the band material with about 0.3% elongation, when loaded to its MSL, makes steel band sensitive for loosing pre-tension if cargo shrinks or settles down. Therefore, the suitability of steel band for cargo securing is limited and national restrictions on their use in road or rail transport should always be considered. The use of steel bands for lashing purposes should be avoided on open CTUs as a broken lashing could be of great danger if it hangs outside the CTU.

Figure 7.19 Metal ingots unitized by steel banding (securing not completed)

2.4.17 Twisted soft wire should be used for minor securing demands only. The strength of soft wire lashings in terms of MSL is scarcely determinable and their elastic elongation and restoring force is poor.

2.4.18 Modular lashing systems with ready-made web lashings are available in particular for general purpose freight containers, to secure cargo against movement towards the door. The number of lashings should be calculated depending on the mass of the cargo, the MSL of the lashings, the lashing angle, the friction factor, the mode of transport, and the MSL of the lashing points in the freight container.

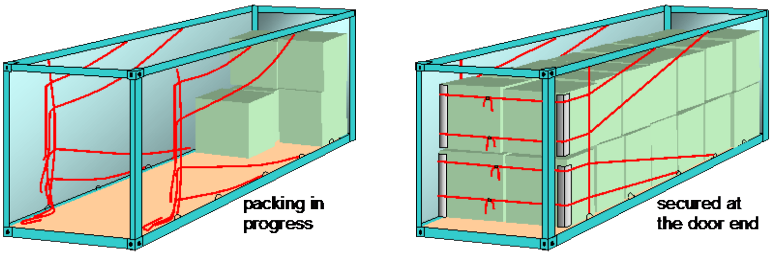

Figure 7.20 Modular lashing system

2.4.19 In the example shown in figure 7.20, the lashings are connected to the lashing points of the CTU with special fittings and are pre-tensioned by means of buckles and a tensioning tool. More information may be obtained from the producers or suppliers of such modular systems.

3 Principles of packing

3.1 Load distribution

3.1.1 Freight containers, flatracks and platforms are designed according to ISO standards, amongst others, in such a way that the permissible payload P, if homogeneously distributed over the entire loading floor, can safely be transferred to the four corner posts under all conditions of carriage. This includes a safety margin for temporary weight increase due to vertical accelerations during a sea passage. When the payload is not homogeneously distributed over the loading floor, the limitations for concentrated loads should be considered. It may be necessary to transfer the weight to the corner posts by supporting the cargo on strong timber or steel beams as appropriate (see figure 7.21).

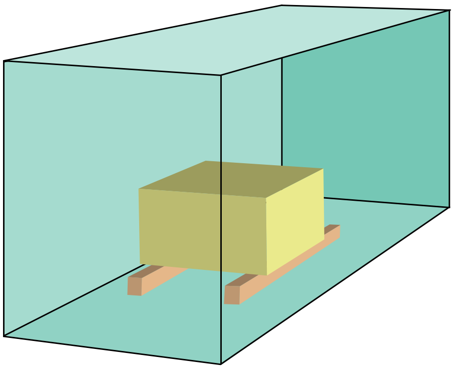

Figure 7.21 Load transfer beams

3.1.2 The bending strength of the beams should be sufficient for the purpose of load transfer of concentrated loads. The arrangement, the required number and the strength of timber beams or steel beams should be designed in consultation with the CTU operator.

3.1.3 Concentrated loads on platforms or flatracks should be similarly expanded by bedding on longitudinal beams or the load should be reduced against the maximum payload. The permissible load should be designed in consultation with the CTU operator.

3.1.4 Where freight containers, including flatracks or platforms, will be lifted and handled in a level state during transport, the cargo should be so arranged and secured in the freight container that its joint centre of gravity is close to the mid-length and mid-width of the freight container. The eccentricity of the centre of gravity of the cargo should not exceed $\pm 5\%$ in general. As a rule of thumb this can be taken as 60% of the cargo's total mass in 50% of the freight container's length. Under particular circumstances an eccentricity of up to $\pm 10\%$ could be accepted, as advanced spreaders for handling freight containers are capable of adjusting for such eccentricity. The precise longitudinal position of the centre of gravity of the cargo may be determined by calculation (see appendix 4 to this annex).