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Group of Experts for the revision of the IMO/ILO/UNECE Guidelines for Packing of Cargo Transport Units

Fourth session
Geneva, 4 – 6 November 2013
Item 6 (a) of the provisional agenda
Proposals for amendments to the final draft of the CTU Code:
Proposals for amendments

Proposed text for Annex 14, Appendix 5

Recommendations by the IMO Working Group on Container Safety

[Appendix 5: Based on the tests and calculations the following text is proposed for appendix 5 based on **option 2** for this section. [When the formulas in this appendix have been agreed upon, user-friendly tables are proposed to be developed.]

1 Resistivity of transverse battens

1.1 The attainable resistance forces F of an arrangement of battens may be determined by the formula:

$$F = n \cdot \frac{w^2 \cdot h}{28 \cdot L} \text{ [kN]}$$

n =	number of battens
w =	thickness of battens [cm]
h =	height of battens [cm]
L =	free length of battens [m]

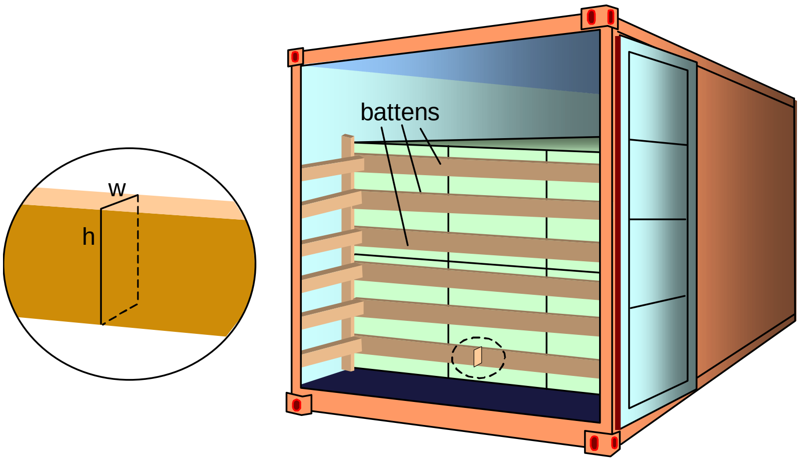

Figure 14.69 – Transverse battens in an ISO container

Example:

A fence of six battens has been arranged. The battens have a free length L = 2.2 m and the cross-section w = 5 cm, h = 10 cm. The total attainable resistance force is:

This force of 24 kN would be sufficient to restrain a cargo mass (m) of 7.5 t, subjected to accelerations in sea area C [(see paragraph 5.3 of the Code)] with 0.4 g longitudinally (c_x) and 0.8 g vertically (c_z). The container is stowed longitudinally. With a friction coefficient between cargo and container floor of μ = 0.4 the following balance calculation shows:

$c_x \cdot m \cdot g < \mu \cdot m \cdot (1-c_z) \cdot g + F$ [kN]

$$0.4 \cdot 7.5 \cdot 9.81 < 0.4 \cdot 7.5 \cdot 0.2 \cdot 9.81 + 24 \text{ [kN]}$$

$$29 < 6 + 24 \text{ [kN]}$$

$$29 < 30 \text{ [kN]}$$

2 Beams for bedding of concentrated loads ~~in an ISO box-container~~

2.1 Bedding arrangements for concentrated loads in general purpose ISO series 1 freight containers, flatracks or platforms should be designed in consultation with the supplier or operator of the cargo transport unit. If no specific advice is available the provisions described in this section should be applied.

2.2 The centre of gravity of a concentrated load should be placed close to half the length of the ~~container~~ cargo transport unit. If more than one concentrated load shall be packed into ~~a container~~ or onto a cargo transport unit, the centres of gravity of the units should as far as possible be placed at distances in terms of ~~container~~ unit length as shown in the table below:

Number of concentrated loads	Suitable longitudinal stowage position
2	1/4 3/4
3	1/7 1/2 6/7
4	1/8 3/8 5/8 7/8

2.3 Short or narrow cargoes may overload the floor structure. This may be prevented either by using longitudinal support beams underneath the cargo to distribute the load over more transverse flooring beams, or by the use of transverse beams, to distribute the load towards the strong side structures of the cargo transport unit.

2.5 When longitudinal support beams are used, their minimum length should be calculated in accordance with sections 2.8 through 2.15 below and the material and the cross section dimensions of the beams should be chosen in accordance with sections 3.1 through 3.5 below. The beams should be placed as far apart as possible, near the edge of the cargo.

2.6 When four longitudinal support beams instead of two beams are used, these should be arranged as straddled twin-beams.

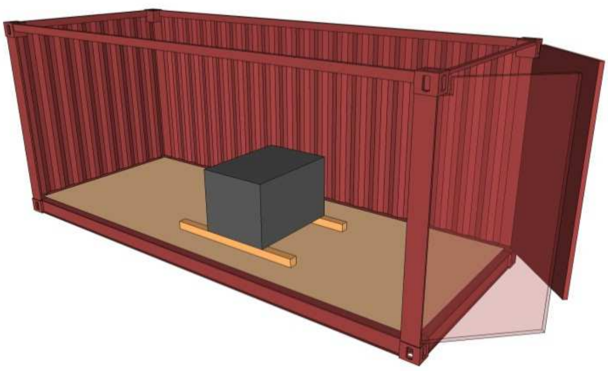

Figure 14.70 – Narrow cargo placed on longitudinal support beams

2.7 When transverse support beams are used, their length should equal the inner width of the container or the width of the platform in case of a flatrack. The material and the cross section dimensions of the beams should be chosen in accordance with sections 3.1 and 3.6 below.

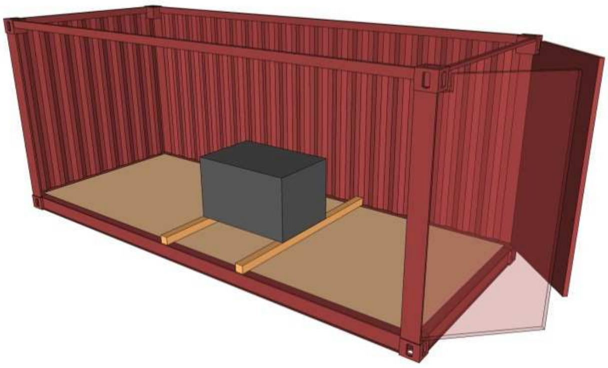

Figure 14.71 – Narrow cargo placed on transverse support beams

Longitudinal strength of containers

2.8 The minimum length of a cargo which is resting on supports near the side beams of a general purpose ISO container is:

$$r = 2 \cdot L \cdot \left(\frac{m}{P} - 0.75 \right)$$ [m] (Need only be calculated if **m** is greater than 75% of **P**)

P = declared payload [t]
m = concentrated load [t]
L = full length of loading floor [m]
r = length of cargo foot print or bridging distance [m]

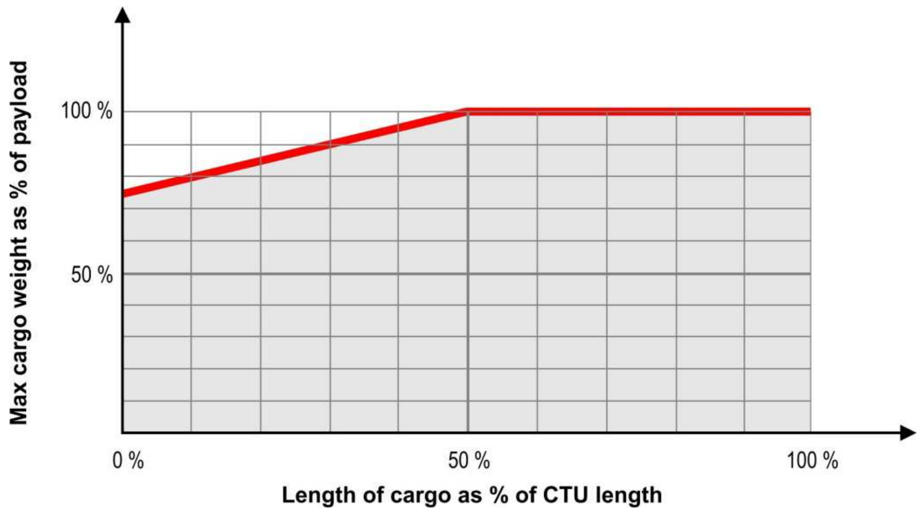

Figure 14.72 – Load distribution for general purpose ISO containers

2.9 If the length of the cargo is less than the required length according to the formula above, the cargo should be bedded with longitudinal beams designed in accordance with sections 3.1 through 3.5 below.

Longitudinal strength of flatracks

2.10 If a cargo unit is placed with its entire foot print over the length r on a flatrack or platform, the minimum length of the cargo is:

$$r = L \cdot \left(2 - \frac{2 \cdot P + T}{2 \cdot m}\right) \text{ [m]}$$

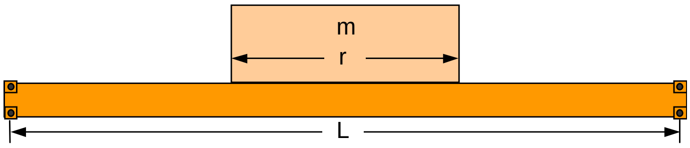

Figure 14.73 – Concentrated load on an ISO platform

2.11 If the cargo unit is rigid and stowed on transverse beddings that bridge the distance r on the flatrack or platform, the minimum length of the cargo is:

$$r = L \cdot \left(1 - \frac{2 \cdot P + T}{4 \cdot m}\right) \text{ [m]}$$

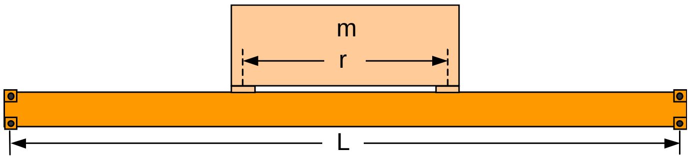

Figure 14.74 – Concentrated load bridging the distance r

P = declared payload [t]
T = declared tare weight [t]
m = concentrated load [t]
L = full length of loading floor [m]
r = length of cargo foot print or bridging distance [m]

2.12 If the length of the cargo is less than the required length according to the formulas above, the cargo should be bedded with longitudinal beams designed in accordance with sections 3.1 through 3.5 below.

Transverse strength of container and flatrack flooring

2.13 In order not to overload the transverse structure of the floor, , it should be checked that cargo in containers and flatracks which are approved in accordance with C.S.C. have at least the following length:

$$r = 0.2 \cdot m \cdot (2.3 - s) \text{ [m]}$$

2.14 For containers and flatracks which are built and tested in accordance with ISO 1496, the the minimum length of cargo can be calculated as:

$$r = 0.15 \cdot m \cdot (2.3 - s) \text{ [m]}$$

r = bottom length of the cargo unit in the container (footprint) [m]
s = width of cargo foot print [m]
m = mass of cargo unit [t]

2.15 If the length of the cargo is less than the required length according to the formulas above, the cargo should be placed on bedding arrangements in accordance with sections 3.1 through 3.6 below.

3 Bending strength of beams

3.1 The permissible bending stress **σ** should be taken as 2.4 kN/cm² for timber beams and 22 kN/cm² for steel beams. The section modulus for a single beam should be obtained from supplier's documents. The following tables may serve as a quick reference:

timber: dimensions [cm]	10 x 10	12 x 12	15 x 15	20 x 20	25 x 25
section modulus [cm³]	152	260	508	1236	2450

steel: dimensions [cm]	12 x 12	14 x 14	16 x 16	18 x 18	20 x 20
section modulus [cm³]	144	216	311	426	570

Longitudinal support beams

3.2 The minimum length of longitudinal bedding beams t should be taken as the minimum required cargo length according to sections 2.8 through 2.15 above.

3.3 The required bending strength of beams should be determined by the formula:

$$n \cdot W = \frac{246 \cdot m \cdot K}{\sigma} \quad [\text{cm}^3]$$

W =	section modulus of one beam [cm³]
n =	number of parallel beams
m =	mass of package [t]
K =	Form factor of bedding beam as defined in section 3.4 and 3.5 below
σ=	permissible bending stress in beam [kN/cm²]

1. If the cargo unit is **flexible**, so that it will rest over its entire length on the bedding beams, the form factor **K** should be calculated according to below:

$$K = t - r \quad [\text{cm}^3]$$

t =	length of the beam [m]
r =	loaded length of beam (footprint) or bridging distance [m]

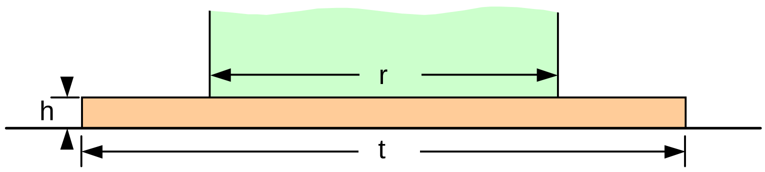

Figure 14.75 – Beam for load spreading under a flexible package

2. If the package is **rigid** so that it will bridge a distance on the bedding beams, the form factor **K** should be calculated according to below:

$$K = \frac{(t-r)^2}{t} \qquad [\text{cm}^3] \text{ if } t > 1.7 \cdot r$$

$$K = 2 \cdot r - t \qquad [\text{cm}^3] \text{ if } t \leq 1.7 \cdot r$$

t =	length of the beam [m]
r =	loaded length of beam (footprint) or bridging distance [m]

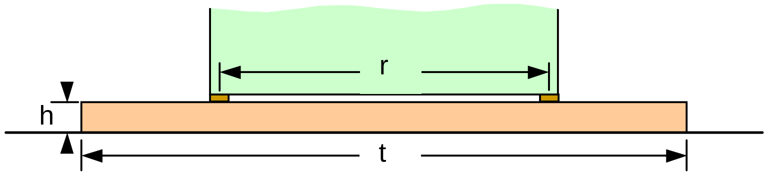

Figure 14.76 – Beam for load spreading under rigid package

Transverse support beams

3. The required bending strength of transverse bedding beams should be determined by the following formulas:

Rigid cargo: $n \cdot W = \frac{590 \cdot m \cdot (2.3 - s) - 3270 \cdot l_e}{\sigma}$

Flexible cargo: $n \cdot W = \frac{220 \cdot m \cdot (4.6 - s) - 2450 \cdot l_e}{\sigma}$

W	=	*Section modulus of support beams [cm^3]*
n	=	*Number of support beams*
m	=	*Cargo weight, [ton]*
s	=	*Width of cargo foot print [m]*
σ	=	*Permissible stress in support beams, [kN/cm^2]*
l_e	=	*Contributing length of container floor [m], taken as the minimum of*

*Beams spaced **more** than 0.84 m apart:* $l_e = 3 \cdot n \cdot 0.28$

*Beams spaced **less** than 0.84 m apart:* $l_e = r + 0.56$

4 Longitudinal position of the centre of gravity in a CTU

4.1 The longitudinal position of the centre of gravity within the inner length of a loaded container is at the distance d from the front, obtained by the formula:

$$d = \frac{T \cdot 0.5 \cdot L + \sum (m_i \cdot d_i)}{T + \sum m_i}$$

d =	distance of common centre of gravity from the front of stowage area [m]
T=	tare mass of the CTU. [t]
L=	length of stowage area (inner length) [m]
m_n =	mass of the individual packages or overpack [t]
d_n =	distance of centre of gravity of mass m_n from front of stowage area [m]

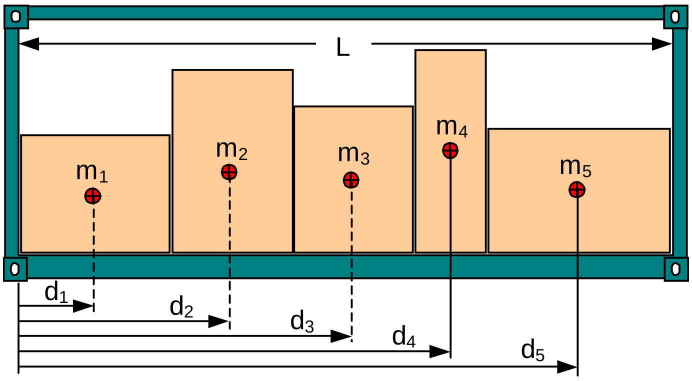

Figure 14.77 – Determination of longitudinal centre of gravity

Example:

A 20' container with inner length L = 5.9 m and tare mass T = 2.3 t is loaded with five groups of cargo parcels as follows:

	m_i [t]	d_i [m]	$m_i \cdot d_i$ [t·m]
1	3.5	0.7	2.45
2	4.2	1.4	5.88
3	3.7	3.0	11.10
4	2.2	3.8	8.36
5	4.9	5.1	24.99
	$\Sigma m_i = 18.5$		$\Sigma(m_i \cdot d_i) = 52.78$

$$d = \frac{T \cdot 0.5 \cdot L + \sum(m_i \cdot d_i)}{T + \sum m_i} = \frac{2.3 \cdot 0.5 \cdot 5.9 + 52.78}{2.3 + 18.5} = \frac{59.565}{20.8} = 2.86 \text{ m}$$

5 Cargo securing with dunnage bags

5.1 Introduction

5.1.1 Accelerations in different directions during transport may cause movements of cargo, either sliding or tipping. Dunnage bags, or air bags, used as blocking device may be able to prevent these movements.

Footnote: Dunnage bags may not be used to secure dangerous goods on US railways

5.1.2 The size and strength of the dunnage bag are to be adjusted to the cargo weight so that the permissible lashing capacity of the dunnage bag, without risk of breaking it, is larger than the force the cargo needs to be supported with:

$$F_{DUNNAGE\ BAG} \geq F_{CARGO}$$

5.2 Force on dunnage bag from cargo (F_{CARGO})

5.2.1 The maximum force, with which rigid cargo may impact a dunnage bag, depends on the cargo's mass, size and friction against the surface and the dimensioning accelerations according to the formulas below:

Sliding:

$$F_{CARGO} = m \cdot g \cdot (c_{x,y} - \mu \cdot 0.75 \cdot c_z)\ [kN]$$

Tipping:

$$F_{CARGO} = m \cdot g \cdot (c_{x,y} - b_p/h_p \cdot c_z)\ [kN]$$

F_{CARGO} = force on the dunnage bag caused by the cargo [t]

m = mass of cargo [t]

$c_{x,y}$ = Horizontal acceleration, expressed in g, that acts on the cargo sideways or in forward or backward directions

c_z = Vertical acceleration that acts on the cargo, expressed in g

μ = Friction factor for the contact area between the cargo and the surface or between different packages

b_p = Package width for tipping sideways, or alternatively the length of the cargo for tipping forward or backward [m]

h_p = package height [m]

5.2.2 The load on the dunnage bag is determined of the movement (sliding or tipping) and the mode of transport that gives the largest force on the dunnage bag from the cargo.

5.2.3 It is only the cargo mass that actually impacts the dunnage bag that shall to be used in the above formulas. The movement forward, when breaking for example, the mass of the cargo behind the dunnage bag is to be used in the formulas.

5.2.4 If the dunnage bag instead is used to prevent movement sideways, the largest total mass of the cargo that either is on the right or left side of the dunnage bag is to be used, that is, either the mass m_1 or m_2, see figure 4.6.

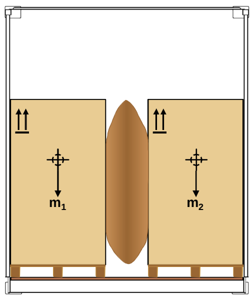

Figure 14.78 – Equal height packages

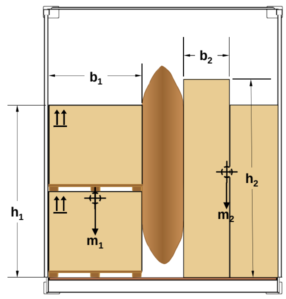

Figure 14.79 – Unequal height packages

5.2.5 In order to have some safety margin in the calculations, the **lowest** friction factor should be used, either the one between the cargo in the bottom layer and the platform or between the layers of cargo.

5.2.6 If the package on each side of the dunnage bag has different forms, when tipping the relationship between the cargo width and height of the cargo stack that have the smallest value of b_p / h_p is chosen.

5.2.7 However, in both cases the total mass of the cargo that is on the same side of the dunnage bag is to be used, that is, either the mass m_1 or m_2 in Figure 4.7.

5.3 Permissible load on the dunnage bag (F_{DB})

5.3.1 The force that the dunnage bag is able to take up depends on the area of the dunnage bag which the cargo is resting against and the maximum allowable working pressure. The force of the dunnage bag is calculated from:

$$F_{DB} = A \cdot 10 \cdot g \cdot P_B \cdot SF \text{ [kN]}$$

F_{DB} =	force that the dunnage bag is able to take up without exceeding the maximum allowable pressure (kN)
P_B =	bursting pressure of the dunnage bag [bar]
A =	contact area between the dunnage bag and the cargo [m^2]
SF =	safety factor
	0.75 for single use dunnage bags
	0.5 for reusable dunnage bags

5.4 Contact area (A)

5.4.1 The contact area between the dunnage bag and the cargo depends on the size of the bag before it is inflated and the gap that the bag is filling. This area may be approximated by the following formula:

$$\mathbf{A = (b_{DB} - \pi \cdot d/2) \cdot (h_{DB} - \pi \cdot d/2)}$$

b_{DB} =	width of dunnage bag [m]
h_{DB} =	height of dunnage bag [m]
A =	contact area between the dunnage bag and the cargo [m^2]
d =	gap between packages [m]
π =	3.14

5.5 Pressure in the dunnage bag

5.5.1 Upon application of the dunnage bag it is filled to a slight overpressure. If this pressure is too low there is a risk that the dunnage bag come loose if the ambient pressure is rising or if the air temperature drops. Inversely, if the filling pressure is too high there is a risk of the dunnage bag to burst or to damage the cargo if the ambient pressure decreases, or if the air temperature rises.

5.5.2 The bursting pressure (P_B) of a dunnage bag depends on the quality, size and the gap that the bag is filling. The pressure that the dunnage bag is experiencing as a result of forces acting from the cargo may never come close to bursting pressure as the bag is in danger of bursting and thus a safety factor according to above shall be used.]