Informal meeting on Code of Practice for Packing of Cargo Transport Units

at the request of the United Nations Economic Commission for Europe Working Party on Intermodal Transport and Logistics

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Bedding Arrangements

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This document proposes changes to section 2 of Appendix 4 (Specific packing and securing calculations) of Annex 7 in order to provide the background and detailed calculations for the design of bedding arrangements described in document 9 for section 3.1 of Annex 7.

Background:

This document introduces formulas for determining the minimum length and bending resistance of bedding beams in freight containers. The design principles are based on the work and guidelines previously published by the TT Club and CINS as well as GDV and MariTerm AB.

This is information is primarily given for the purpose of providing the background for the tables in document 9 as requested at previous meetings of the informal working group. It is at this stage not recommended that the Code is complimented with this content unless there is a strong will to do so by the informal working group. But, should that be the case, the proposed text in this document has been formulated to be suited for pasting into the already available chapter in Appendix 4 for this topic.

At the end of this document, example calculations are given to show that the formulas in this document and the tables previously introduced in document 9 give the same result. Please note that these examples are **not** intended to form part of the proposed text.

Proposed text:

2. Bedding a concentrated load in a general purpose freight container ~~or on a flatrack~~

2.1 Introduction

2.1.1 Bedding arrangements for concentrated loads in general purpose freight containers ~~and on flatracks~~ should be designed in consultation with the CTU operator.

2.1.2 The minimum length and bending resistance (section modulus) of bedding beams should be taken from the tables in Section 3.1 of this annex or by the formulas presented below.

2.2 Minimum length

2.2.1 The minimum length of bedding beams, L_R, can be calculated by following formula:

$$L_R = 0.165 \cdot m \cdot (2.3 - B)$$

Where:

L_R = Minimum length of bedding beams (m)
m = mass of cargo (t)
B = Spacing of bedding beams (m)

2.2.2 In addition, where the cargo mass is greater than 50% of the Payload, the length of bedding beams, L_R, should also not be less than:

$$L_R = \left(\frac{m}{P} - 0.5\right) \cdot L_{CTU}$$

Where:

L_R = Minimum length of bedding beams (m)
m = mass of cargo (t)
P = Payload of CTU (t)
L_{CTU} = Length of CTU (m)

2.3 Minimum section modulus

2.3.1 The minimum section modulus, W, for bedding beams can be calculated by the following formula:

$$W = \frac{125 \cdot m \cdot g \cdot (L_R - L_C)}{n \cdot \sigma_p}$$

Where:

W = Minimum section modulus of bedding beams (cm^3)
m = mass of cargo (t)
L_R = Minimum length of bedding beams as given in section 2.2 (m)
L_C = Length of cargo footprint on bedding beams (m)
n = number of bedding beams
σ_p = Permissible bending stress of material in beams (N/mm^2)

Examples and comparison to tables in Document 9

The tables previously introduced in document 9 are based on the formulas presented in this document. Below are a few examples to show how the formulas have been used to calculate the values in the tables.

Example 1 – Minimum length based on beam spacing

For a cargo weighing 20 tonnes and where the bedding beams are spaced 1.0 meters apart, the minimum length of the beams will be:

$$L_R = 0.165 \cdot m \cdot (2.3 - B) = 0.165 \cdot 20 \cdot (2.3 - 1) = 4.3\ m$$

Where:
L_R = Minimum length of bedding beams (m)
m = mass of cargo = 20 t
B = Spacing of bedding beams = 1.0 m

This is the same result as is given in Table X.1 in document 9 for **cargo mass 20 tonnes** and beam **spacing 1.00 m**:

Minimum required length of longitudinal bedding beams, L_R, [m]							
Spacing between beams, B [m]	**Cargo mass [ton]**						
	4	**8**	**12**	**16**	**20**	**24**	**28**
0.50	1.2	2.4	3.6	4.8	6.0	-	-
0.75	1.0	2.1	3.1	4.1	5.1	6.2	-
1.00	0.9	1.7	2.6	3.4	4.3	5.2	6.0
1.25	0.7	1.4	2.1	2.8	3.5	4.2	4.9
1.50	-	1.1	1.6	2.1	2.6	3.2	3.7
1.75	-	0.7	1.1	1.5	1.8	2.2	3.0
2.00	-	-	0.6	0.8	1.3	2.1	3.0

Table X.1

Example 2 – Section modulus of wooden beams

According to the formula in this document, the minimum section modulus for 2 bedding beams that are 4.3 meters long, where the cargo weighs 20 tonnes and it's footprint is 2.8 meters long, will be:

$$W = \frac{125 \cdot m \cdot g \cdot (L_R - L_C)}{n \cdot \sigma_p} = \frac{125 \cdot 20 \cdot g \cdot (4.3 - 2.8)}{2 \cdot 15} = 1226 \text{ cm}^3$$

Where:

W = *Minimum section modulus of bedding beams (cm³)*

m = *mass of cargo = 20 t*

L_R = *Minimum length of bedding beams as given in section 2.2 = 4.3 m*

L_C = *Length of cargo footprint on bedding beams = 2.8 m*

n = *number of bedding beams = 2 pcs*

σ_p = *Permissible bending stress of material in beams = 15 N/mm²*

According to basic principles for engineering, the section modulus for a square cross section with height and width "a", can be calculated as:

Section modulus, $W = \frac{a^3}{6}$

Thus, the minimum height and width for the wooden beams in this example can be calculated as:

Height and width, $a = \sqrt[3]{W \cdot 6} = \sqrt[3]{1226 \cdot 6}$ *= 19.4 cm = 194 mm*

For comparison, the free length of the bedding beams in this example is according to the revised version of document 9 defined as:

Free length $= \frac{L_R - L_C}{2} = \frac{4.3 - 2.8}{2}$ *= 0.75 m*

Minimum height and width, "a" ~~a × a~~, of a pair of square wooden beams with σ_p = 1.5 kN/cm² [mm]							
Free length (L_R - L_C) / 2 [m]	Cargo mass [tonnes]						
	4	8	12	16	20	24	28
~~0.5~~ 0.25	79	99	114	125	135	143	151
~~1.0~~ 0.50	99	125	143	158	170	181	190
~~1.5~~ 0.75	114	143	164	181	194	207	218
~~2.0~~ 1.00	125	158	181	199	214	227	239
~~2.5~~ 1.25	135	170	194	214	231	245	258
~~3.0~~ 1.50	143	181	207	227	245	260	274
~~3.5~~ 1.75	151	190	218	239	258	274	289
~~4.0~~ 2.00	158	199	227	250	270	287	302

Table X.2