INTERNATIONAL STANDARD

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Freight containers — Straddle carriers for freight container handling — Calculation of stability

Conteneurs pour le transport de marchandises — Chariots cavaliers pour la manutention des conteneurs — Calcul de la stabilité

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Contents

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 14829 was prepared by Technical Committee ISO/TC 104, *Freight containers*, Subcommittee SC 1, *General purpose containers.*

Annex A of this International Standard is for information only.

Introduction

This International Standard specifies the criteria to be considered when calculating the static and dynamic stability of straddle carriers for handling freight containers.

Freight containers — Straddle carriers for freight container handling — Calculation of stability

1 Scope

This International Standard specifies the calculations to be carried out to determine the stability of a straddle carrier.

The stability calculations specified in this International Standard are intended to ensure that users of straddle carriers have adequate information about the behaviour of these carriers under various operating conditions.

Stability warning and control devices are not covered by this International Standard.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 668:1995, *Series 1 freight containers — Classification, dimensions and ratings*

ISO 4302:1981, *Cranes — Wind load assessment*

ISO 3874:1997, *Series 1 freight containers — Handling and securing*

3 Terms and definitions

For the purposes of this International Standard, the following terms and definitions apply.

3.1
straddle carrier for freight container handling
mobile handling equipment with main directions of movement, travelling and lifting which is not restricted to a fixed path and of which the guided lifting device is suitable for the lifting and horizontal movement of containers

NOTE 1　　Lifting is by a lift frame attached to the top of the container by twistlocks.

NOTE 2　　During normal operations, the centre of gravity of the lifting spreader is always between the tipping lines determined by the supporting points. See Figure 1.
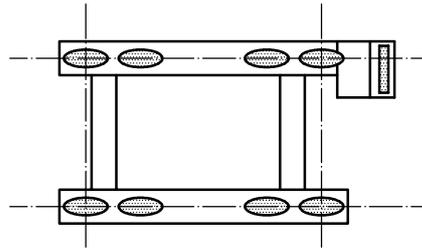
Figure 1 — Tipping lines

NOTE 3   Where "straddle carrier" is used in the text hereafter, "straddle carrier for freight container handling" is to be understood.

3.2
tipping lines
transverse and longitudinal centrelines of the outermost tyres

NOTE   See Figure 1.

3.3
limit of stability
point at which the sum of moments causing tipping is greater than the sum of moments aiding stability

4   Symbols and abbreviated terms

The symbols and abbreviated terms are given in Table 1.

Table 1

Symbol	Description	Unit of measure
a_x	Maximum deceleration due to maximum braking	m/sec^2
b	Ground slope	%
C_l	Stability ratio-longitudinal	
COG	Centre of gravity	
C_t	Stability ratio-transverse	
F_w	Wind force	N
g	Gravity	m/sec^2
l	Distance from centre of front tyre to centre of rear tyre	m
m	Sum of all masses of straddle carrier	kg
M_c	Tipping moment due to centrifugal force	N·m
M_d	Tipping moment due to deceleration	N·m
M_r	Righting moment	N·m
M_t	Tipping moment	N·m
M_w	Tipping moment due to wind	N·m
R	Turning radius at centre of straddle carrier at ground plane	m

Table 1 *(continued)*

Symbol	Description	Unit of measure
R_{min}	Minimum turning radius at centre of straddle carrier at ground plane	m
R_{COG}	Turning radius of centre of gravity	m
S	Stability ratio	
v	Speed of centre of straddle carrier at ground plane	m/sec
v_{max}	Maximum possible speed of centre of straddle carrier at ground plane	m/sec
v_{COG}	Speed of centre of gravity	m/sec
w	Distance between centreline of tyres	m
x_{ecc}	Longitudinal eccentricity of total mass	m
y_{ecc}	Transverse eccentricity of total mass	m
z_{COG}	Vertical height of centre of gravity	m
z_w	Vertical height of wind force	m
Δx	Longitudinal shift of COG	m
Δx_{fr}	Longitudinal shift of COG due to frame deflection	m
Δx_{sl}	Longitudinal shift of COG due to slope	m
Δx_{su}	Longitudinal shift of COG due to suspension deflection	m
Δx_{ty}	Longitudinal shift of COG due to tyre deflection	m
Δy	Transverse shift of COG	m
Δy_{fr}	Transverse shift of COG due to frame deflection	m
Δy_{sl}	Transverse shift of COG due to slope	m
Δy_{su}	Transverse shift of COG due to suspension deflection	m
Δy_{ty}	Transverse shift of COG due to tyre deflection	m

5 Design considerations

5.1 Limit of stability

It shall be determined at which travelling speed at a range of turning radii, including the minimum turning radius, the straddle carrier is stable. The longitudinal stability shall be determined and the maximum wind speed at which the straddle carrier is stable when not in service shall be determined (static mode).

5.2 Load conditions of straddle carrier

The load conditions of the straddle carrier are given in Table 2.

Table 2

Case	Container designation	Mass kg	Position of spreader
1	1 AAA	30 480 (fully laden)	Top
2	1 AAA	5 000 (tare weight)	Bottom of container 1 metre above ground
3	No container	—	Top
4	No container	—	Underside of spreader 3 metres above ground
5	No container	—	Lowest position

5.3 Items which affect stability

5.3.1 Wind load and direction of wind

The wind effect on the straddle carrier shall be as specified in ISO 4302.

The wind speed shall be 20 m/s as specified in ISO 4302:1981, Table 1, item b.

When, for a particular terminal, the actual wind speed is greater than 20 m/s, then additional calculations shall be made accordingly.

The direction of the wind is to be taken as perpendicular to the tipping line.

The wind effect on the carried load shall be based on container dimensions as specified in ISO 668.

5.3.2 Reaction of suspension

Suspension deflection shall be taken into consideration.

5.3.3 Tyre deflection

Tyre deflection shall be taken into consideration. The tyres should be at their recommended "in service" pressures.

5.3.4 Grade of surface

Stability calculations shall incorporate a ground slope of 2 %. When designing for a particular terminal whose actual slope differs from the 2 % level, additional calculations shall be performed.

The slope is the tangent of the angle of inclination of the surface to the horizontal, multiplied by 100 as shown in Figure 2.
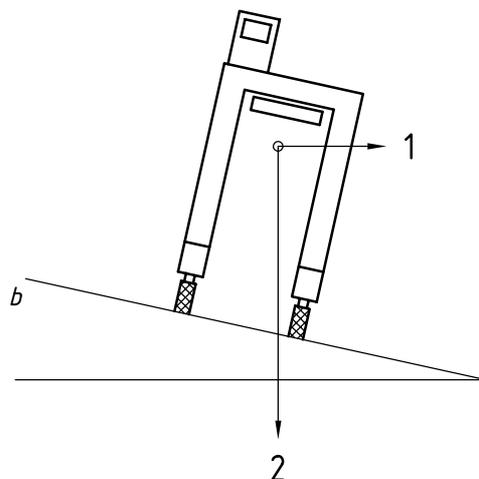
Key

1   Horizontal component
2   Vertical component

Figure 2 — Ground slope

5.3.5   Load distribution of content of container

The contents of the container shall be loaded as specified in ISO 3874. Specifically, the eccentric weight distribution of the contents of the container shall be as follows:

— the longitudinal eccentricity shall be an even load distribution with a maximum of 5 % deviation at either end;

— the transverse eccentricity shall be an even load distribution with a maximum of 5 % deviation at either side.

The vertical centre of gravity of a loaded container shall be at 50 % of the total height of the container.

The condition that results in the poorest stability shall be used.

5.3.6   Position of spreader

The spreader shall be centred. The height of the spreader shall be in accordance with the load cases given in 5.2.

5.3.7   Condition of all fluid tanks

The condition of the fuel oil tanks shall be 50 % full, unless stability is decreased with a full fuel tank, in which case a full fuel tank shall be used. The condition of all other tanks containing fluids shall be at the nominal level.

5.3.8   Speed and turning radius

The speed shall be the speed at the ground plane of the centre of the straddle carrier.

The turning radius is the radius at the ground plane of the centre of the straddle carrier.

NOTE   The turning radius of the vehicle, as defined by the vehicle engineers, is not the same as the path followed by the centre of gravity of the mass.

5.3.9 Mass of driver

The weight of the operator (driver) shall be included at a value of 90 kg when occupying a normal operating position.

5.3.10 Deflection of straddle carrier structure during operations

The deflection of the straddle carrier structure shall be taken into account in the stability calculations. Figure 6 shows a graphical representation of the deflection phenomenon on slopes.

5.3.11 Centre of gravity for the equipment and its moving parts

The centre of gravity for the equipment and its moving parts shall be determined by calculations, based on the following:

a)   the centre of gravity of that part of the structure which does not move when the load is elevated;

b)   the centre of gravity of the spreader which moves in unison with the load;

c)   the centre of gravity of any other part of the equipment which moves as the load is elevated, but does not maintain a constant position with respect to the load and is not capable of being combined with 5.3.11 d);

d)   the centre of gravity of any other part of the equipment which is capable of movement, and thus of influencing the position of the centre of gravity of the whole, during normal operation.

Items may be included with the main structure, provided that the centres of gravity of such items are taken to be in a position which has the least beneficial effect on the stability of the straddle carrier as a whole.

5.4   Safety of operator

The possibility exists that a straddle carrier may overturn during normal operations owing to a combination of circumstances. The operator of the straddle carrier is responsible for the safe operation of the equipment. The operator of the equipment shall receive in-depth training before being allowed to work with a straddle carrier.

6   Stability calculations

6.1   Stability ratio

The calculations specified in 6.5 define the stability ratio between the righting moment and the tipping moment.

The minimum stability ratios are:

—   transverse (C_t) for load cases 1 through 4:   1,25

—   transverse (C_t) for load case 5:   1,10

—   longitudinal (C_l) for load case 1:   1,15

The ratio takes into account a safety factor to cover the manufacturing variances, allowances for wind surges, sudden changes in operating terrain and operator error.

6.2   Determination of co-ordinates

The co-ordinates for all calculations are shown in Figure 3.
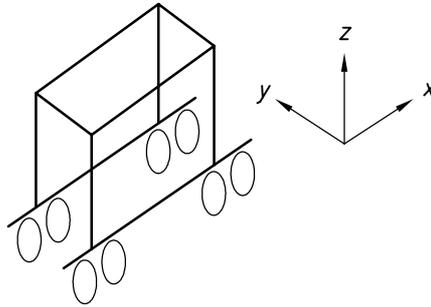
Key

x = Longitudinal
y = Transverse
z = Vertical

Figure 3 — Determination of co-ordinates

6.3   Variable dimensions — Transverse stability calculations

The variable dimensions pertinent to the calculation of transverse stability are shown in Figure 4.
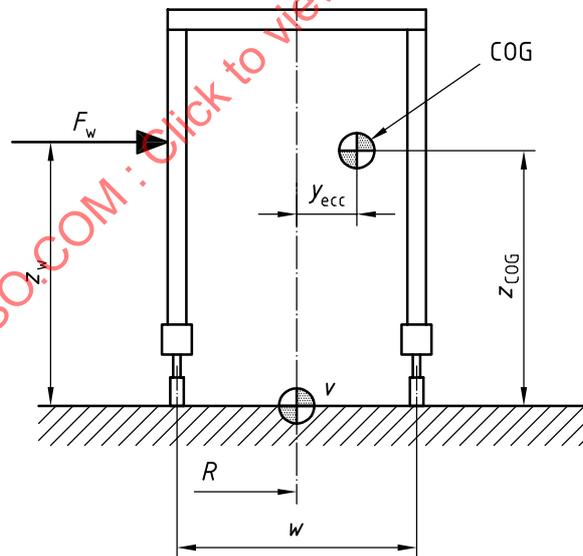

Figure 4 — Variable dimensions — Transverse stability

6.4 Variable dimensions — longitudinal stability calculations

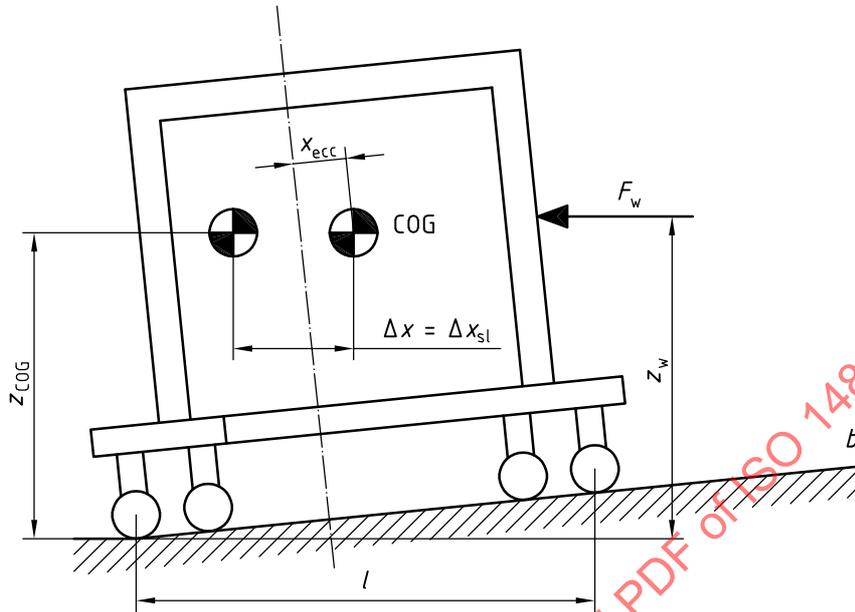The variable dimensions pertinent to the calculation of longitudinal stability are shown in Figure 5.

**Figure 5 — Variable dimensions — Longitudinal stability**

6.5 Formulae for stability calculations

6.5.1 Transverse stability

The following formulae shall be used when calculating:

a) the stability during cornering using load cases 1 through 4 from 5.2 and incorporating the stability ratios from 6.1;

b) the maximum wind speed using load case 5 from 5.2 (out of service condition, $v = 0$) and incorporating the stability ratios from 6.1.

The deflection on slopes is shown in Figure 6.

Key
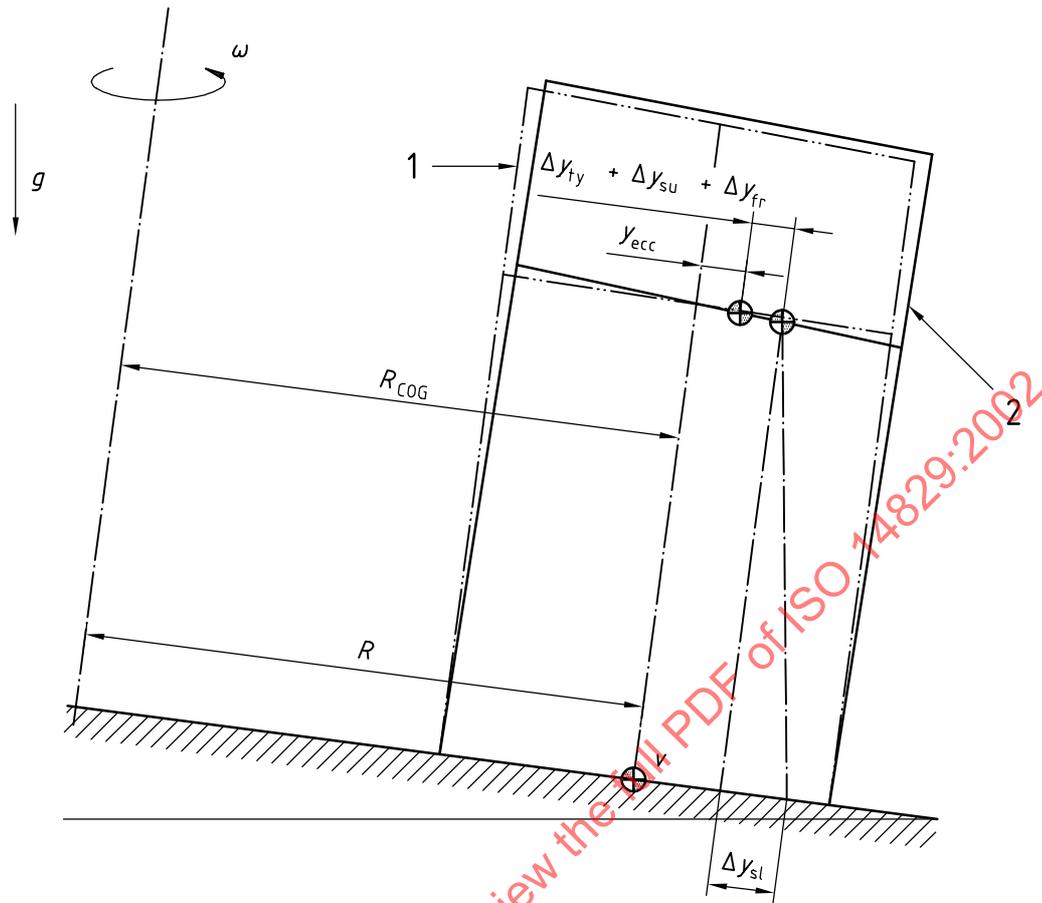
1 Undeflected carrier
2 Deflected carrier due to suspension, tyres and frame

— · · — · · — Carrier on slope

— · — · — · — Deflection of suspension, tyres & frame

Figure 6 — Deflection on slopes

$$C_t = \frac{M_r}{M_t}$$

$$M_t = M_w + M_c$$

$$M_r = m_{COG}\left(\frac{w}{2} - y_{ecc} - \Delta y - \Delta y_{sl}\right)g$$

$$M_w = \sum F_{w,i} \times Z_{w,i}$$

$$M_c = m_{COG} \times \frac{V_{COG^2}}{R_{COG}} \times z_{COG}$$

$$R_{COG} = R + y_{ecc} + \Delta y$$

$$\Delta y = \Delta y_{\text{ty}} + \Delta y_{\text{su}} + \Delta y_{\text{fr}} \text{ (see NOTE)}$$

$$v_{\text{COG}} = \frac{R_{\text{COG}}}{R} \times v$$

$$S = \frac{M_{\text{r}}}{C_{\text{t}} \left(M_{\text{w}} + M_{\text{c}} \right)}$$

NOTE   If Δy is not calculated by iteration, the maximum possible value corresponding to the tipping over case applies.

6.5.2 Formulae for calculation of longitudinal stability

Load case 1 from 5.2 shall be used.

The following formulae shall be used when calculating whether the actual value for C_{l} meets the requirements for C_{l} as prescribed in 6.1.

$$C_{\text{l}} = \frac{M_{\text{r}}}{M_{\text{t}}}$$

$$M_{\text{t}} = M_{\text{w}} + M_{\text{d}}$$

$$M_{\text{w}} = \sum \left(F_{\text{w,i}} \times Z_{\text{w,i}} \right)$$

$$M_{\text{d}} = m \times Z_{\text{COG}} \times a_{\text{x}}$$

$$M_{\text{r}} = m \left(\frac{l}{2} - x_{\text{ecc}} - \Delta x - \Delta x_{\text{sl}} \right) g$$

$$\Delta x = \Delta x_{\text{ty}} + \Delta x_{\text{su}} + \Delta x_{\text{fr}} \text{ (see NOTE)}$$

NOTE   If Δx is not calculated by iteration, the maximum possible value corresponding to the tipping over case applies.