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10.1.2018

Wind calculation report

ConFoot leg with 20´/40´ DC container

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1 General

In this report, wind forces and container stability against overturning under wind forces are calculated. This report has been made following the guidelines of standard *EN 1991-1-4:2005+A1 Eurocode 1: Actions on structures - Part 1-4: General actions - Wind actions.*

In calculations it is assumed that there is no sliding in the contact between ConFoot leg and ground. Friction force between ConFoot leg and ground is not calculated in this report.

1.1 Requirements

20´ DC or 40´ DC container supported with four ConFoot legs should withstand constant wind velocity of **30,5 *m/s*** without overturning. In other words, stability moment caused by container gravity must be equal or greater than overturning moment caused by wind force.

2 Calculations

2.1 Load cases

Figures 1 and 2 shows the free body diagram of container supported with four ConFoot legs under side wind force and under end wind force.

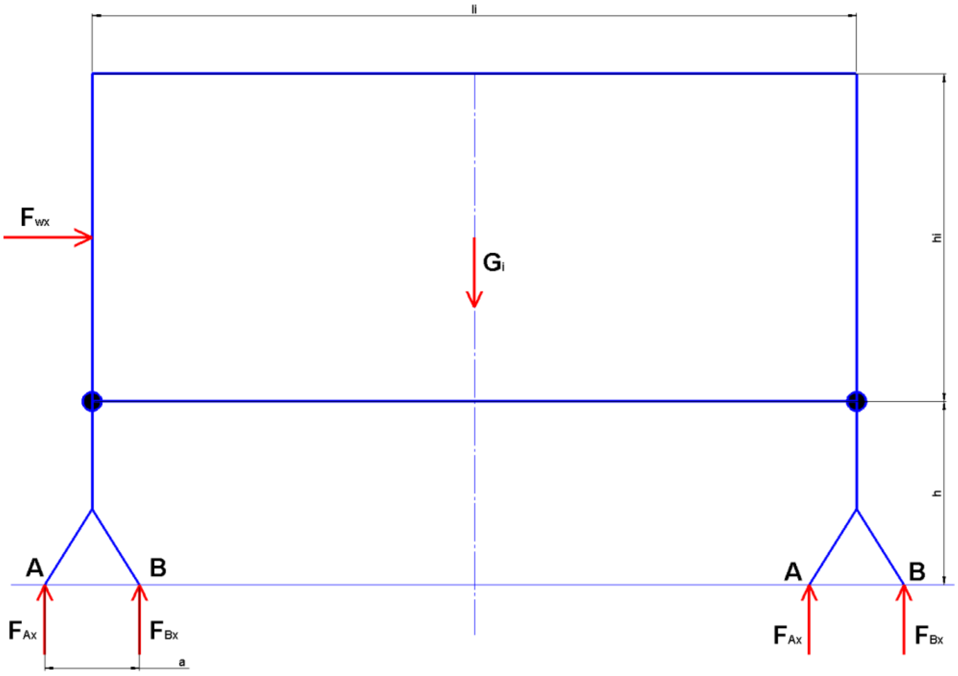


Figure 1. Free body diagram under end wind force.

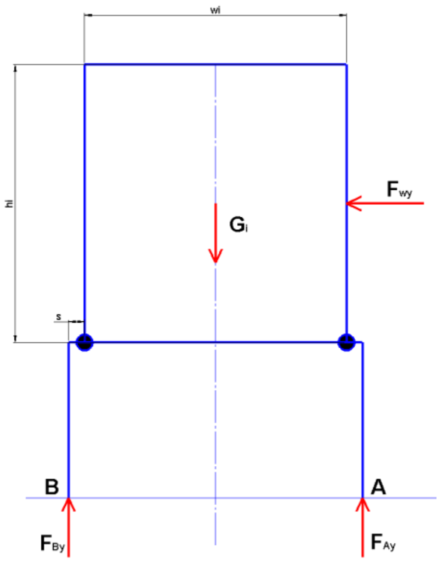


Figure 2. Free bodydiagram under side wind force.

In both load cases critical over turning moment is exceeded when the support force F_{Ai} less or equal to zero.

2.2 Wind pressure and wind force

According to standard *EN 1991-1-4* wind pressure and wind force are following:

$$q_p = 0{,}5 * \rho * v^2$$

, where
ρ air density
v wind velocity

$$F_w = c_{sd} * c_f * q_p * A_{ref}$$

, where
c_{sd} structural factor
c_f friction coefficient
A_{ref} reference area of the individual surface

Wind forces with wind velocity $v = 30{,}5\ \frac{m}{s}$ of different containers and load cases are shown in the table below.

Table 1 Wind forces.

	40´ DC container	**20´ DC container**
End wind	3,34 kN	5,02 kN
Side wind	33,41 kN	18,24 kN

More detailed calculations are shown in annex A.

2.3 Empty container stability under wind force

Support force F_{Ai} can be determined from moment equilibrium (see Fig. 1 and 2). More detailed calculations are shown in annex A. Values of support force F_{Ai} with empty container are shown in table below.

Table 2. Values of support force F_{Ai} *with empty container*

	40´ DC container (empty)	**20´ DC container (empty)**
Container self-weight	3740 kg	2220 kg
F_{Ax}, end wind	2,969 kN	0,297 kN
F_{Ay}, side wind	-7,568 kN	-3,693 kN

Results above show that the stability moment of 20´ and 40´ DC containers self-weight is greater than the overturning moment of end wind force.

However, the overturning moment of side wind force is greater than the stability moment of 20´ and 40´ DC containers self-weight. In order to maintain stability in side wind load case there should be a counter weight at the location of support A. Counter weight should be minimum of 800 kg with 40´DC container and minimum of 400 kg with 20´ DC container.

In table 3 are shown the maximum allowable side wind forces with empty container.

Table 3. Maximum allowable side wind forces with empty container

	40´ DC container (empty)	**20´ DC container (empty)**
Container self-weight	3740 kg	2220 kg
***Max F_{wy}*, side wind force**	18 kN	-10 kN

In table 4 are shown minimum required total weights of containers to maintain stability in side wind load case with wind velocity $v = 30{,}5\ \frac{m}{s}$

Table 4. Minimum required total weights of containers to maintain stability in side wind load case with wind velocity $\mathrm{v} = 30{,}5\ \frac{\mathrm{m}}{\mathrm{s}}$

	40´ DC container (empty)	**20´ DC container (empty)**
Container self-weight	3740 kg	2220 kg
Required total weight	6830 kg	3730 kg
Required additional weight in addition to self-weight	3090 kg	1510 kg

3 Summary

Calculations show that empty 20´ DC or 40´DC container cannot maintain stability under wind forces with wind velocity $v = 30,5\ \frac{m}{s}$. Wind force calculations were made following the guidelines of standard *EN 1991-1-4:2005+A1.*

In order to maintain stability against overturning under side wind forces following recommendations are made:

1. Minimum allowable container self-weight to be according to table 4. Note calculated minimum self-weight is assumed to be evenly distributed.

2. ConFoot legs to be fixed to the ground or additional counterweights to be added according to section 2.3.

3. Maximum rated wind velocity $v = 30,5\ \frac{m}{s}$ to be decreased (see table 3 for maximum allowable wind forces)

4 References

EN 1991-1-4 Eurocode 1: Actions on structures
Part 1-4: General actions - Wind actions

Annex A

172_002_ConFoot leg - Wind calculations
PL / 20180110

$v := 30,5 \frac{m}{s}$ Maximum wind speed

$h := 1450\ mm$ ConFoot leg height

40´DC container dimensions

$l_{40} := 12192\ mm$ $w_{40} := 2440\ mm$ $h_{40} := 2590\ mm$

$G_{40} := 3740\ kg\ g_e = 36,6769\ kN$

20´DC container dimensions

$l_{20} := 6050\ mm$ $w_{20} := 2440\ mm$ $h_{20} := 2590\ mm$

$G_{20} := 2220\ kg\ g_e = 21,7708\ kN$

Peak velocity pressure

$\rho := 1,25 \frac{kg}{m^3}$ Air density

$q_b := 0,5 \cdot \rho \cdot v^2$ Wind pressure (EN 1991-1-4 p. 23 (4.10))

$q_p := q_b = 581,41 \frac{N}{m^2}$ Assumption: constant wind velocity "v" (EN 1991-1-4 (4.8), (4.9))

Wind forces

$F_w := c_{sd} \cdot c_f \cdot q_p \cdot A_{ref}$ The wind force acting on a structure (EN 1991-1-4 (5.3))

$c_{sd} := 1$ For buildings with a height less than 15 m (EN 1991-1-4 p. 28)

$c_f := c_{fo} \cdot \psi_r \cdot \psi_\lambda$ The force coefficient of structural elements of rectangular section with the wind blowing normally to a face (EN 1991-1-4 (7.9))

$\psi_r := 1$ Reduction factor for a square cross-section with rounded corners => sharp corners =1 (EN 1991-1-4 Fig. 7.24)

$\varphi := 1$ $\lambda := 70$ Effective slenderness λ, end-effect factor ψ.λ and solidity ratio φ (EN 1991-1-4 Table 7.16 No. 4 and Fig. 7.36)

=> $\psi_\lambda := 0,91$

End wind force container 40´DC

$A_{ref} := w_{40} \cdot h_{40} = 6,32\ m^2$

$\frac{l_{40}}{w_{40}} = 5$ => $c_{fo} := 1,0$ Force coefficients Cf,0 of rectangular sections with sharp corners and without free end flow (EN 1991-1-4 Fig. 7.23)

=> $c_f = 0,91$

$F_{wx40} := F_w = 3,34\ kN$

Side wind force container 40´DC

$A_{ref} := h_{40} \cdot l_{40} = 31,58\ m^2$

$\frac{w_{40}}{l_{40}} = 0,2$ => $c_{fo} := 2,0$ => $c_f = 1,82$

$F_{wy40} := F_w = 33,41\ kN$

End wind force container 20´DC

$A_{ref} := w_{20} \cdot h_{20} = 6,32\ m^2$

$\frac{l_{20}}{w_{20}} = 2,48$ => $c_{fo} := 1,5$ => $c_f = 1,36$

$F_{wx20} := F_w = 5,02\ kN$

Side wind force container 20´DC

$A_{ref} := h_{20} \cdot l_{20} = 15,67\ m^2$

$\frac{w_{20}}{l_{20}} = 0,4$ => $c_{fo} := 2,2$ => $c_f = 2$

$F_{wy20} := F_w = 18,24\ kN$

Stability againts end wind force

$h = 1450\ mm \quad a := 750\ mm$

$F_{Ax40}(G) := \frac{G}{8} - \frac{F_{wx40} \cdot h}{4 \cdot a}$ $\quad$ $F_{Ax20}(G) := \frac{G}{8} - \frac{F_{wx20} \cdot h}{4 \cdot a}$

$F_{Ax40}(G_{40}) = 2968,55\ N$ $\quad$ $F_{Ax20}(G_{20}) = 297,26\ N$

$F_{Ax40}(12,95\ kN) = 2,69\ N$ $\quad$ $F_{Ax20}(19,4\ kN) = 0,91\ N$

Stability againts side wind force

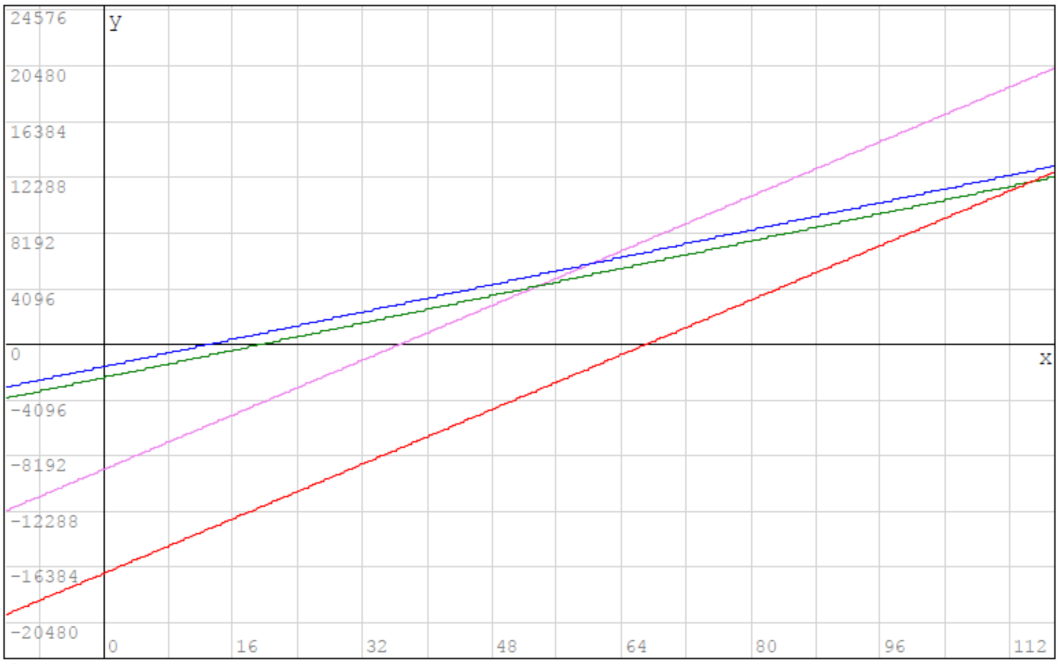
$s := 150\ mm$

$F_{Ay40}(G) := \frac{\frac{G}{2} \cdot \left(s + \frac{w_{40}}{2}\right) - \frac{F_{wy40}}{2} \cdot \left(h + \frac{h_{40}}{2}\right)}{2 \cdot s + w_{40}}$ $\quad$ $F_{Ay20}(G) := \frac{\frac{G}{2} \cdot \left(s + \frac{w_{20}}{2}\right) - \frac{F_{wy20}}{2} \cdot \left(h + \frac{h_{20}}{2}\right)}{2 \cdot s + w_{20}}$

$F_{Ay40}(G_{40}) = -7568,17\ N$ $\quad$ $F_{Ay20}(G_{20}) = -3693,41\ N$

$F_{Ay40}(66,94954\ kN) = 0\ N$ $\quad$ $F_{Ay20}(36,5444\ kN) = 0\ N$

Critical support force F,A as a function of container gravity force G



$F_{Ax40}(x\ kN)$
$F_{Ay40}(x\ kN)$
$F_{Ax20}(x\ kN)$
$F_{Ay20}(x\ kN)$