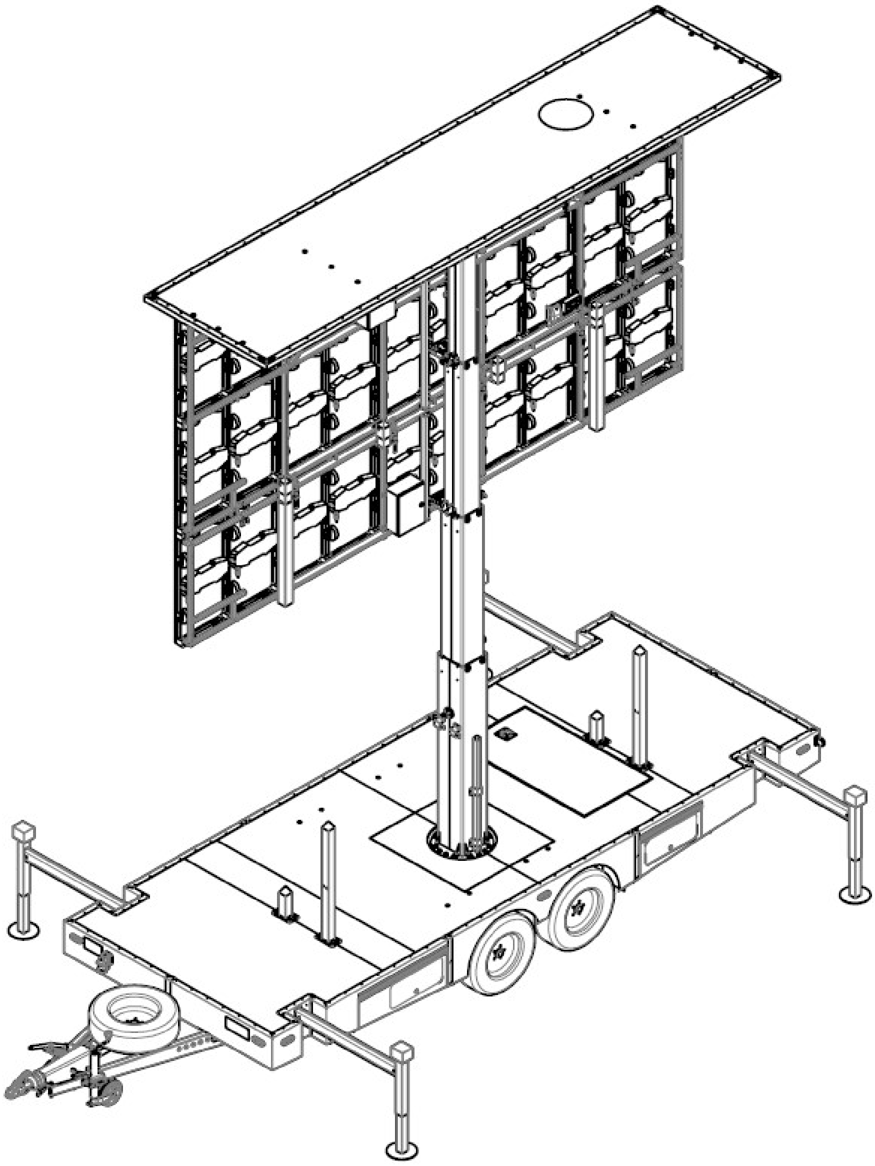
# Calculation of static

# Trailer PlatformLED 15m$^2$



Inowrocław, P15AUD-2

12.06.2024

# 1. Introduction

There is a description in this document of analysis performed to check operating limitations during use of this machine:

- Determination of critical and safe (stable) wind speed and reactions in supports.
- Determination of wind speed limits as a result of stress in construction

Calculations were performed based on the analytical method and FEM (Finite-element method) method.

# 2. Calculations

Two cases of load were considered due to screen setting, and wind direction (Fig. 2.1).

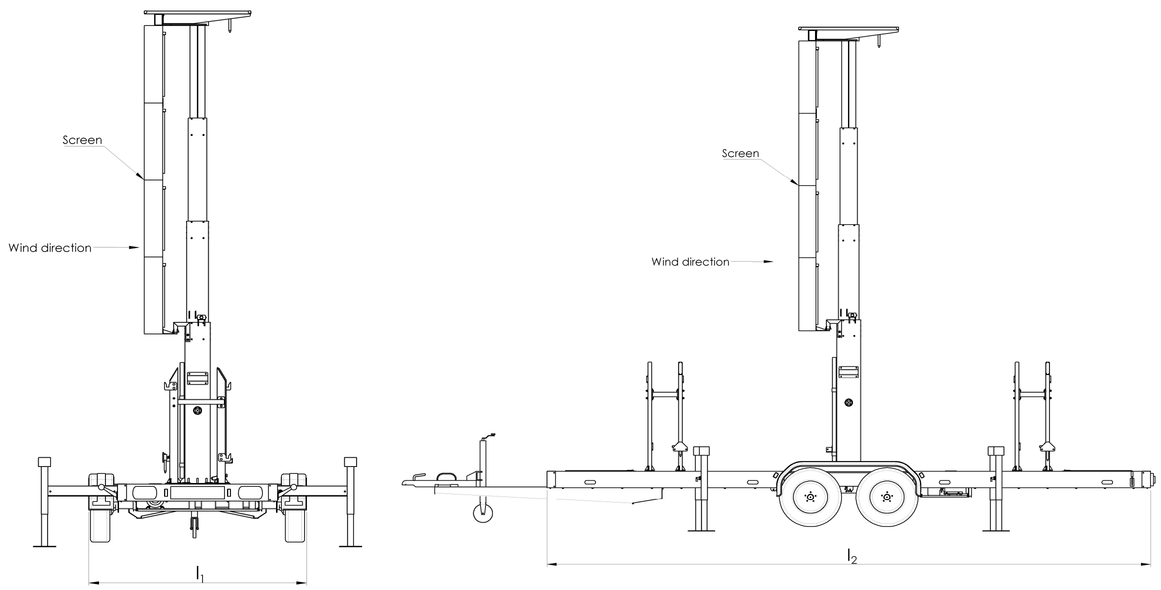



Fig. 2.1. Cases of loads due to wind direction and screen setting.

## 2.1 The first load case - wind blowing from the side

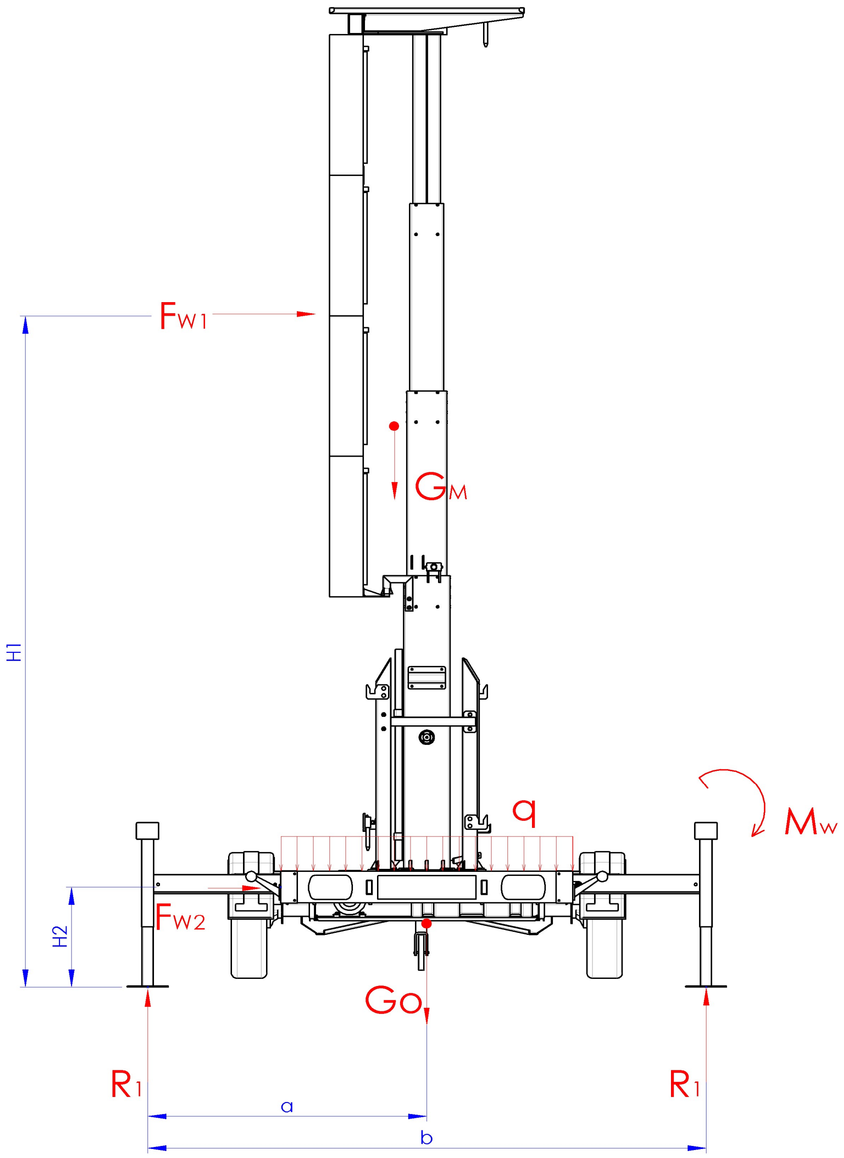



Fig. 2.2. The first load case-distribution of forces and torques.

**Drawing reference:**

$R_1$- reaction in the first support(windward)

$R_2$- reaction in the second support(leeward)

$G_O$ - axle weight

q - construction weight (frame, container, instrumentation)

$G_M$ - mast weight

$F_{W1}$ - wind force on the screen

$F_{W2}$ - wind force on the side surface of the container

$M_W$ - resultant torque of wind

| Calculation constants | |
|---|---|
| Acceleration due to gravity [m/s^2] | 9,81 |
| Partial safety factor | 1,35 |
| Wind safety factor | 1,2 |
| Aerodynamic coefficient | 1,8 |
| Friction μ (sand,gravel-wood) | 0,65 |
| Friction μ (wood-concrete) | 0,6 |
| Field point for steel 355 fy [MPa] | 355 |
| Safety factor (yield) γ | 1,1 |

| Weight of components and generated loads | | | |
|---|---|---|---|
| | Weight [kg] | Load [N] | Shown in Fig. 2.2. |
| Mast+screen | 1200 | 11772 | $G_M$ |
| Frame+container+instrumentation | 1600 | 15696 | p |
| Axle | 230 | 2256,3 | $2G_O$ |
| Catch | 80 | 784,8 | $G_c$ |
| The total weight of the trailer $N_k$ | 3110 | 30509,1 | |

| Dimensions [mm] (Fig. 2.2) | |
|---|---|
| a | 1819 |
| b | 4100 |
| l2 | 5500 |
| H1 | 5407 |
| H2 | 380 |
| H3 | 1600 |

| Surfaces | |
|---|---|
| Screen $A_{ref1}$ [$m^2$] | 15 |
| Side surface of the container $A_{ref2}$ [$m^2$] | 2,5 |
| Screen retracted | 15 |

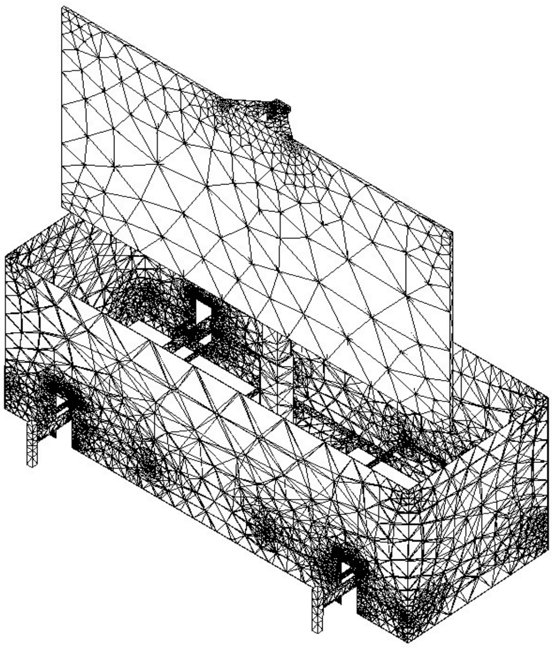


Fig.2.3. Discrete model for FEM calculation

**Wind loads according to EN 13814:**

$$F_w = q_{eq} \times c_f \times A_{ref}$$

$$v_{ref} \square 15 \frac{m}{s} \rightarrow q_{eq} = q_{req} \times ce(ze) \times c_d = 0,2 \frac{kN}{m^2}$$

$$v_{ref} \square 28 \frac{m}{s} \rightarrow q_{eq} = q_{req} \times ce(ze) \times c_d = 0,35 \frac{kN}{m^2}$$

**Verification of stability:**

*The safety against overturning according to EN 13814:*

$$\Sigma\gamma M_{St,k} \geq \Sigma\gamma M_{K,k}$$

$$\Sigma\gamma M_{St,k} = \mathrm{a} \cdot (G_M + 2G_0 + G_c + q)$$

= 1819 · ( 11772 + 15696 + 2256 + 785 ) / 1000000

= **55,5** *kNm*

**LED screen ON**

$$\Sigma\gamma M_{K,k} = \gamma\Sigma F_W \cdot H_i$$

= 1,2 · ( 0,2 · 1,8 · 15 · 5407 / 1000 + 0,2 · 1,8 · 2,5 · 380 / 1000 )

= **35,4** *kNm*

**LED screen OFF**

$$\Sigma\gamma M_{K,k} = \gamma\Sigma F_W \cdot H_i$$

= 1,2 · ( 0,56 · 1,8 · 15 · 1600 / 1000 )

= **29,0** *kNm*

**LED screen OFF for 15m²**

= 1,2 · ( 0,56 · 1,8 · 15 · 1600 / 1000 )

= **29,0** *kNm*

| **Condition of stability** | | | |
|---|---|---|---|
| LED screen ON, Vref=15m/s | 55,5 | ≥ | 35,4 |
| LED screen OFF, Vref=28m/s | 55,5 | ≥ | 29,0 |
| LED screen OFF 15m² | 55,5 | ≥ | 29,0 |

*The safety against sliding according to EN 13814:*

$$\Sigma\gamma\mu N_k \geq \Sigma\gamma H_k$$

$$\mu = 0{,}65$$

$\Sigma\gamma\mu N_k =$ 0,65 · 30509 = **19,8** *kN*

$$\mu = 0{,}6$$

$\Sigma\gamma\mu N_k =$ 0,6 · 30509 = **18,3** *kN*

LED screen ON

$\Sigma\gamma H_k =$ 1,2 · 0,2 · 1,8 · ( 15 + 2,5 )
= **7,56** *kN*

LED screen OFF

$\Sigma\gamma H_k =$ 1,2 · 0,35 · 1,8 · 15
= **11,3** *kN*

| **Condition safety against sliding** | | | |
|---|---|---|---|
| LED screen ON, Vref=15m/s, $\mu$=0,65 | 19,8 | ≥ | 7,6 |
| LED screen OFF, Vref=28m/s, $\mu$=0,65 | 19,8 | ≥ | 11,3 |
| LED screen ON, Vref=15m/s, $\mu$=0,6 | 18,3 | ≥ | 7,6 |
| LED screen OFF, Vref=28m/s, $\mu$=0,6 | 18,3 | ≥ | 11,3 |

The structural strength was calculated against load case from wind vref=15m/s and LED screen ON (like in Fig 2.2) using FEM.
Load combinations and allowable stress was determined according to EN 13814.

## 2.2 The second load case - wind blowing from the front

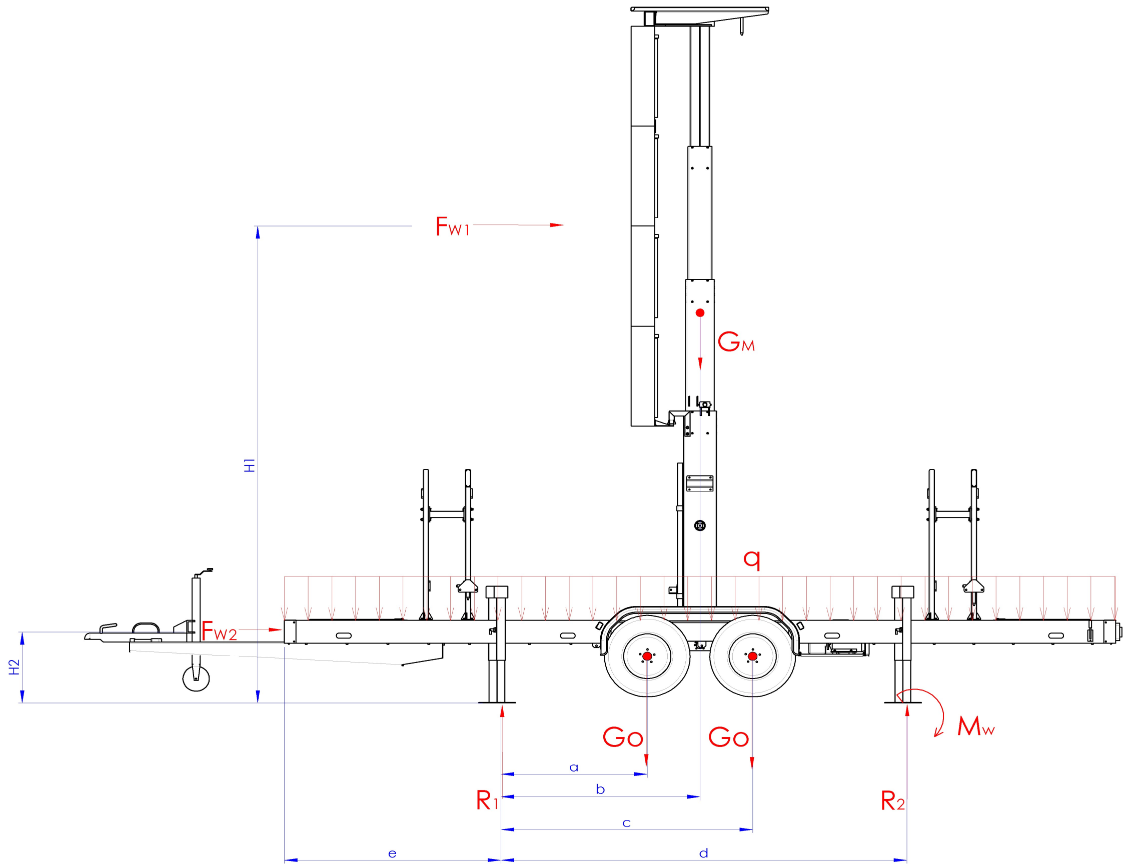



Fig.2.4. Second load case – distribution of forces and torques.

**Drawing reference:**

$R_1$- reaction in the first support (windward)
$R_2$- reaction in the second support (leeward)
$G_O$ - axle weight
q - construction weight (frame, container, instrumentation)
$G_M$ - mast weight
$F_{W1}$ - wind force on the screen
$F_{W2}$ - wind force on the side surface of the container
$M_W$ - resultant torque of wind

| Calculation constants | |
|---|---|
| Acceleration due to gravity [m/s^2] | 9,81 |
| Partial safety factor | 1,35 |
| Wind safety factor | 1,2 |
| Aerodynamic coefficient | 1,8 |
| Friction μ (sand,gravel-wood) | 0,65 |
| Friction μ (wood-concrete) | 0,6 |
| Field point for steel 355 fy [MPa] | 355 |
| Safety factor (yield) γ | 1,1 |

| Weight of components and generated loads | | | |
|---|---|---|---|
| | Weight [kg] | Load [N] | Shown in Fig. 2.2. |
| Mast+screen | 1200 | 11772 | $G_M$ |
| Frame+container+instrumentation | 1600 | 15696 | p |
| Axle | 230 | 2256,3 | $2G_O$ |
| Catch | 80 | 784,8 | Gc |
| The total weight of the trailer $N_k$ | 3110 | 30509,1 | |

| Dimensions [mm] (Fig. 2.4) | |
|---|---|
| a | 1930 |
| b | 2330 |
| c | 2730 |
| d | 4600 |
| e | 424 |
| $l_1$ | 2200 |
| H1 | 5407 |
| H2 | 380 |
| H3 | 1600 |

| Surfaces | |
|---|---|
| Screen $A_{ref1}$ [$m^2$] | 15 |
| Side surface of the container $A_{ref2}$ [$m^2$] | 1 |
| Screen retracted | 15 |

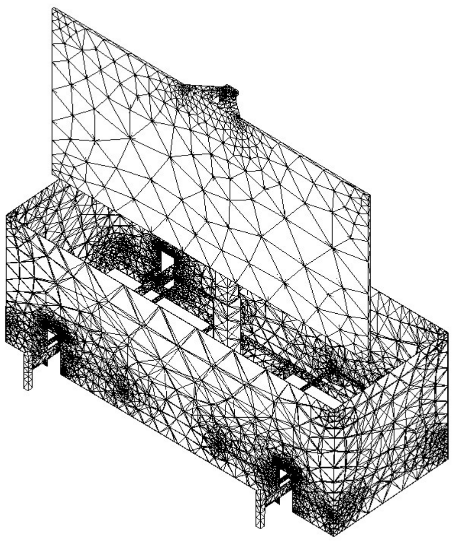


Fig.2.5. Discrete model for FEM calculation

**Wind loads according to EN 13814:**

$$F_w = q_{eq} \times c_f \times A_{ref}$$

$$v_{ref} \square 15\frac{m}{s} \rightarrow q_{eq} = q_{req} \times ce(ze) \times c_d = 0{,}2\frac{kN}{m^2}$$

$$v_{ref} \square 28\frac{m}{s} \rightarrow q_{eq} = q_{req} \times ce(ze) \times c_d = 0{,}35\frac{kN}{m^2}$$

**Verification of stability:**

*The safety against overturning according to EN 13814:*

$$\Sigma\gamma M_{St,k} \geq \Sigma\gamma M_{K,k}$$

$$\Sigma\gamma M_{St,k} = (\mathrm{d} - \mathrm{b}) \cdot (G_M + 2G_0 + q) + (e + d) \cdot G_C$$

= **71,4** *kNm*

**LED screen ON**

$$\Sigma\gamma M_{K,k} = \gamma\Sigma F_W \cdot H_i$$

= 1,2 · ( 0,2 · 1,8 · 15 · 5407 / 1000 + 0,2 · 1,8 · 1 · 380 / 1000 )

= **35,2** *kNm*

**LED screen OFF**

$$\Sigma\gamma M_{K,k} = \gamma\Sigma F_W \cdot H_i$$

= 1,2 · ( 0,56 · 1,8 · 15 · 1600 / 1000 )

= **29,0** *kNm*

**LED screen OFF 14m$^2$**

= 355 · ( 0,56 · 1,8 · 15 · 1600 / 1000 )

= **29,0** *kNm*

| Condition of stability | | | |
|---|---|---|---|
| LED screen ON, Vref=15m/s | 71,4 | ≥ | 35,2 |
| LED screen OFF, Vref=28m/s | 71,4 | ≥ | 29,0 |
| LED screen OFF 14m$^2$ | 71,4 | ≥ | 29,0 |

*The safety against sliding according to EN 13814:*

$$\Sigma\gamma\mu N_k \geq \Sigma\gamma H_k$$

$$\mu = 0{,}65$$

$\Sigma\gamma\mu N_k =$ 0,65 · 30509 = **19,8** *kN*

$$\mu = 0{,}6$$

$\Sigma\gamma\mu N_k =$ 0,6 · 30509 = **18,3** *kN*

LED screen ON

$\Sigma\gamma H_k =$ 1,2 · 0,2 · 1,8 · ( 15 + 1 )
= **6,9** *kN*

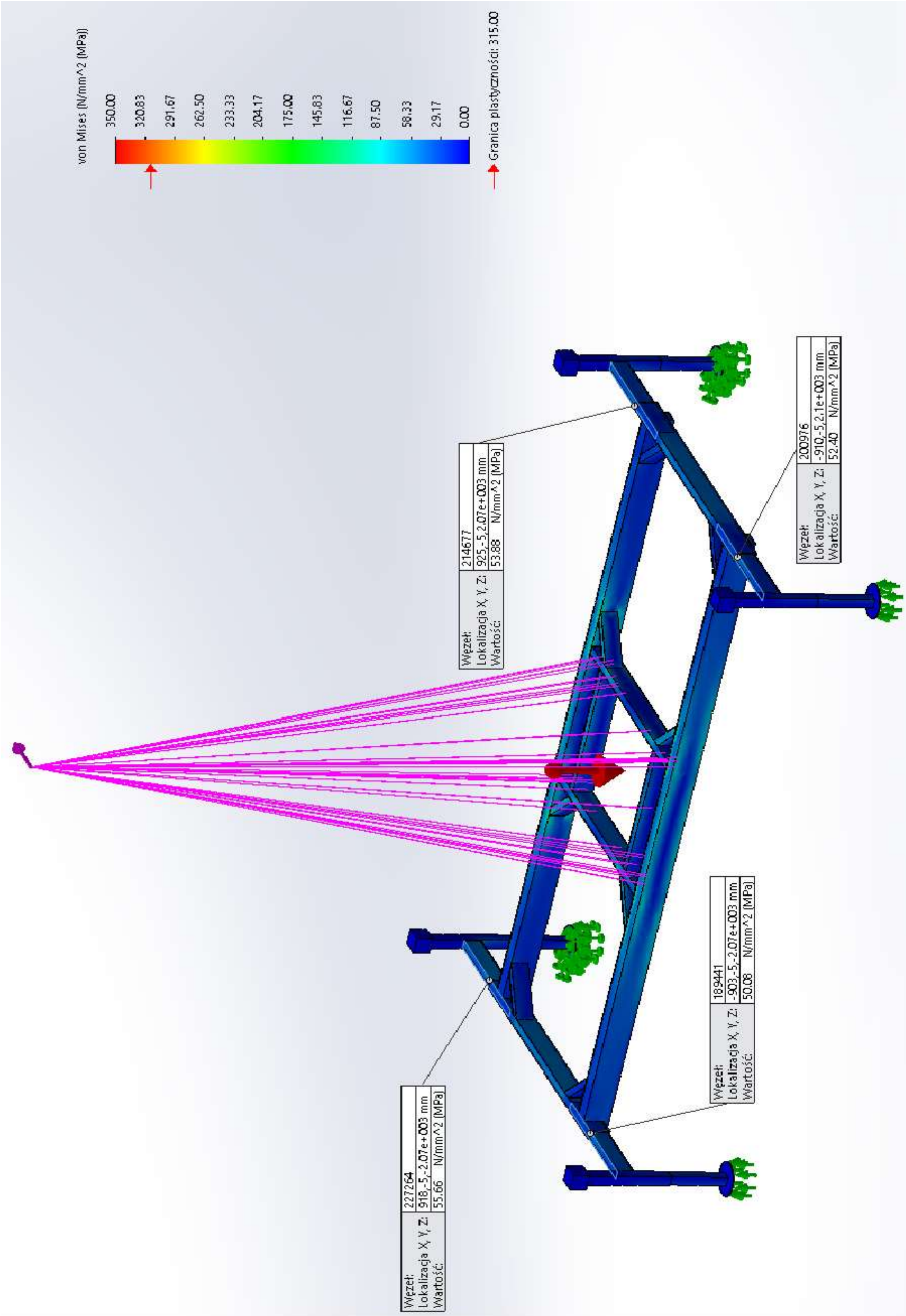
LED screen OFF

$\Sigma\gamma H_k =$ 1,2 · 0,35 · 1,8 · 15
= **11,3** *kN*

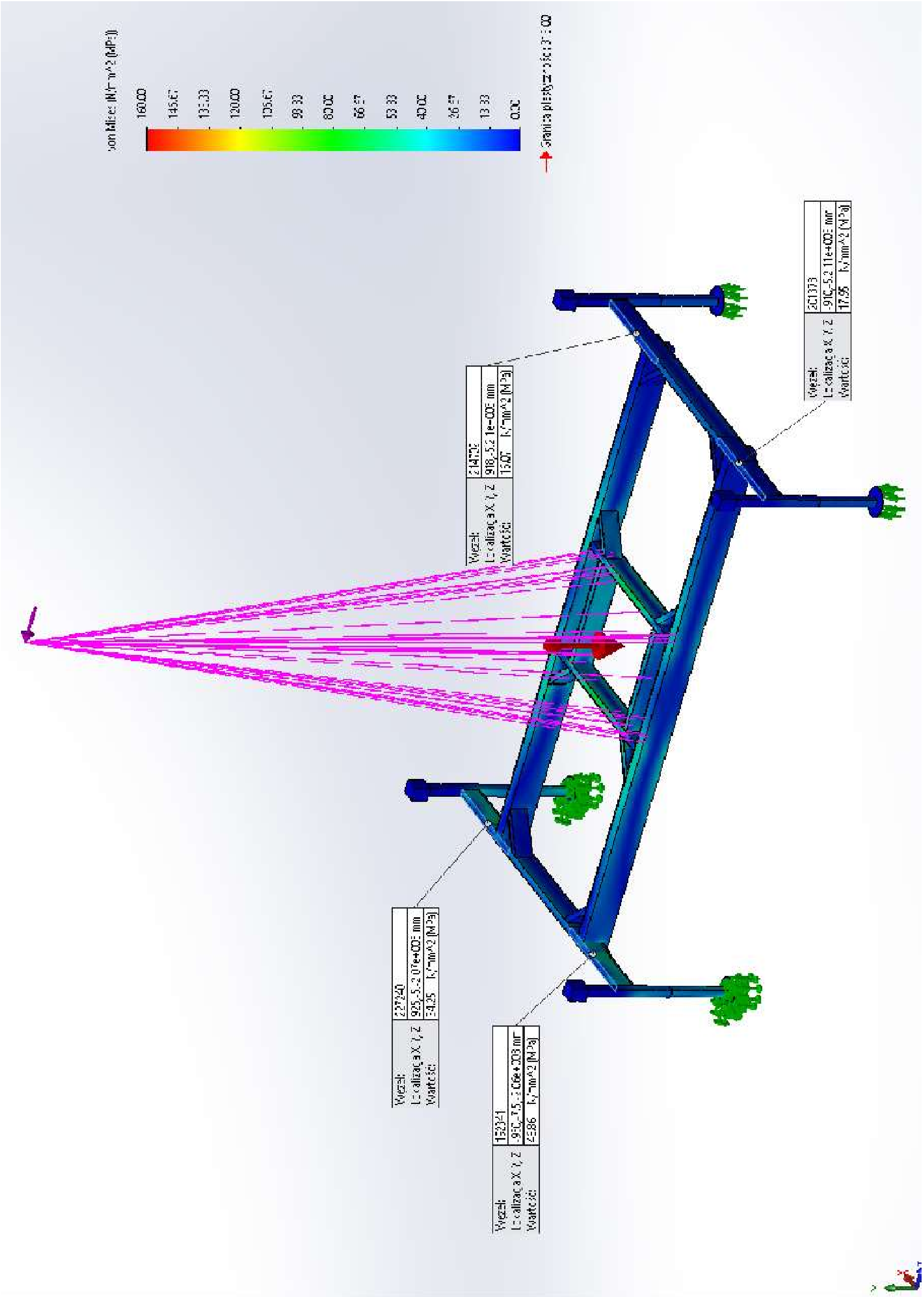
| **Condition safety against sliding** | | | |
|---|---|---|---|
| LED screen ON, Vref=15m/s, $\mu$=0,65 | 19,8 | ≥ | 6,9 |
| LED screen OFF, Vref=28m/s, $\mu$=0,65 | 19,8 | ≥ | 11,3 |
| LED screen ON, Vref=15m/s, $\mu$=0,6 | 18,3 | ≥ | 6,9 |
| LED screen OFF, Vref=28m/s, $\mu$=0,6 | 18,3 | ≥ | 11,3 |

The structural strength was calculated against load case from wind vref=15m/s and LED screen ON (like in Fig 2.2) using FEM.
Load combinations and allowable stress was determined according to EN 13814.

*Wind blowing from the site*



## *Wind blowing from the front*



# 3. Conclusion

In this study there has been performed an analysis of the trailer with the screen against various operating conditions in order to validate the stability of the construction. Calculations, both analytical and finite-element method (FEM), have been implemented for that purpose.

- The trailer can be operated safely at the wind speed up to 15m/s;
- The trailer is safe at the wind speed up to 28m/s in LED screen OFF position (screen retracted)