LED TRAILER STRUCTUAL ANALYSIS

Project No.	
Project	LED TRAILER STRUCTUAL ANALYSIS
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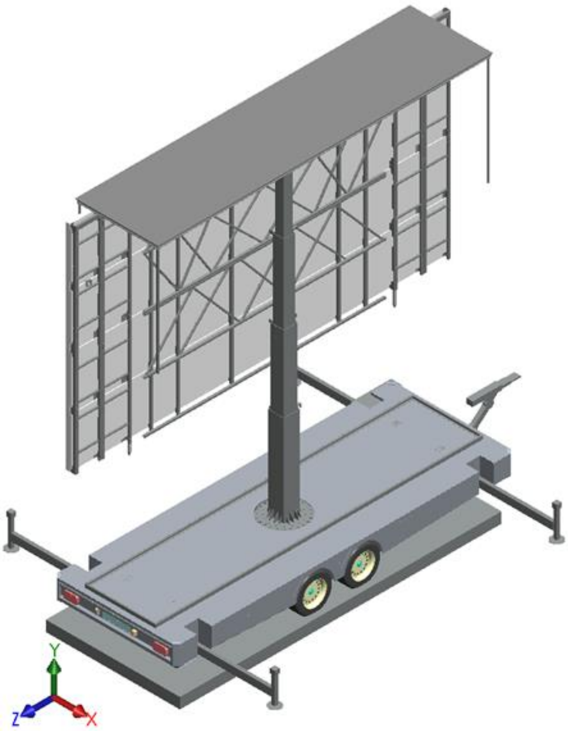
CONTENTS

1. PREAMBLE

1.1. GENERAL NOTES

Report contains structural analysis of trailer frame with LED screen (Fig. 1). Analysis comprise assessment of the operational safety under the wind loading, verification of safety against overturning and strength evaluation of main structural parts.



1 Fig. Isometric view of trailer model with LED screen 7x4m

Trailer calculated for 8 class of Beaufort wind scale load. Wind speed for this class is 17,2 – 20,7 m/s. Structural analysis is made for situation when trailer is raised on supporting legs. Technical data of trailer are presented in table 1.

Table 1

Trailer	Screen				Trailer		Total mass, kg	Height of CG, m
	width b, m	height h, m	Screen mass, kg	Frame mass, kg	Support base z, m	Support base x, m		
73x23	7.0	4.0	960	300	5.26	5.00	3500	2.614

1.2. STANDARDS and SUPPORTING DOCUMENTS

The trailers designed in accordance with the State of the Art and the rules and regulations in force in Lithuania and in the European community.

LST EN 13814:2005 Fairground and amusement park machinery and structures – Safety.

LST EN 1991-1-4:2005/NA:2012 Eurocode 1: Actions on structures – Part 1-4: General actions – Wind actions.

LST EN 13782:2015 Temporary structure – Tents – Safety.

3D drawings and data sheets of the trailer.

2. BASIS FOR DESIGN

2.1. MATERIALS

Main frame parts made of structural steel: **S355**JO in accordance with EN 10025-2.

The nominal values of hot rolled structural steel S355 used in design calculations (in accordance with EN 1993-1-1:2005):

Modulus of elasticity:	210 GPa;
Poisson's ratio:	0.3
Yield strength:	355 MPa
Welds:	accordance with ISO 13920-B
Bolts and Nuts:	8.8 quality minimum

2.2. LOADS

Self-weight and wind load according EN 13814 and EN 1991-1-4:2005

Structure height < 8 m.

LED Screen $b \text{ x } h = 7000 \text{ x } 4000 \text{ mm}$, surface area $A_{ref} = 28 \text{ m}^2$

Dead weight of LED panel: $m_{LED,screen} = 960 \text{ kg}$;

Dead weight of LED screen holding frame without LED panel: $m_{LED,frame} = 300 \text{ kg}$;

Offset distance between CG of screen and pole centre: $x_{CG,LED} = 500 \text{ mm}$.

Trailer loading scheme presented in Fig. 2.

Wind load:

$F_W = q_b \cdot c_f \cdot A_{ref}$ (EN 13814:2004, 5.3.3.4.1)

Basic wind pressure:

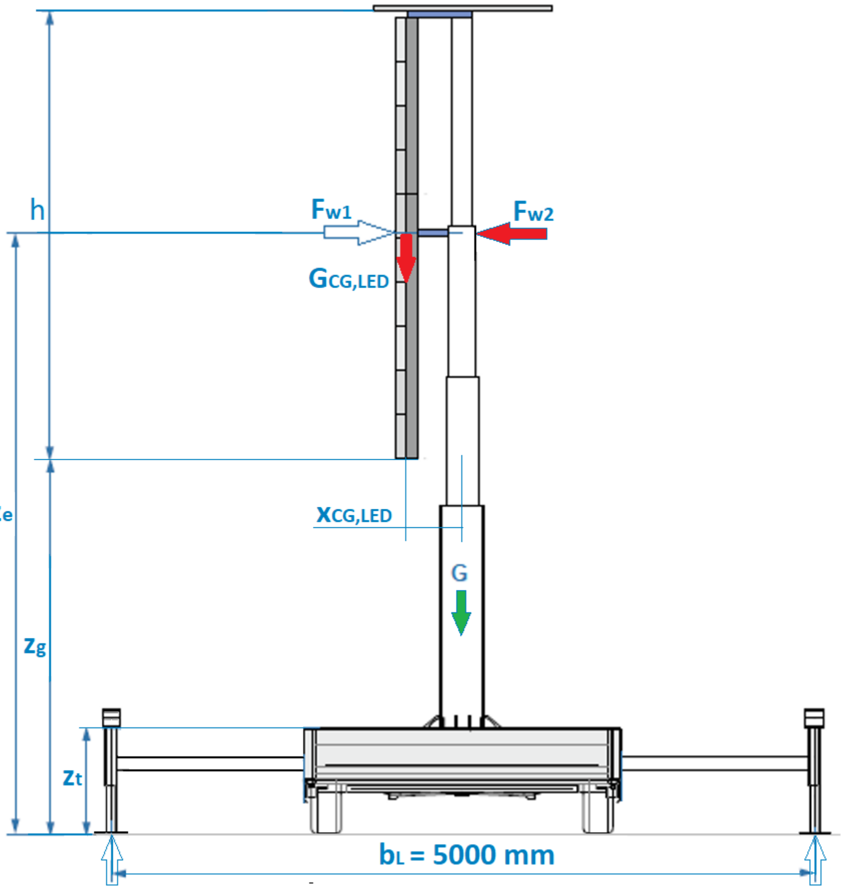
$$q_b = 0.5 \cdot \rho \cdot v_b^2 = 0.5 \cdot 1.25 \cdot 18^2 = 203\ N/m^2$$ (EN 1991-1-4:2005, 4.5(1))

ρ - air density, recommended value is: $\rho = 1.25\ kg/m^3$ (EN 1991-1-4:2005, 4.5(1))

v_b – basic wind velocity, for Beaufort wind scale 8 (17.2÷20.7 m/s),

(https://en.wikipedia.org/wiki/Beaufort_scale)

c_f – force coefficient, $c_f = 1.8$ (EN 1991-1-4:2005, 7.43).



2 Fig. Trailer loading scheme

Load combinations.

Weight load + wind load: $\sum \gamma_G \cdot G_k + \sum \gamma_Q \cdot Q_{k,i} = \sum 1.1 \cdot G_k + 1.35 \cdot F_w$ (EN 13814:2004, 5.3.6.2):

G_k characteristic value of permanent action (weight load); $Q_{k,i}$ characteristic value of one of the variable actions (wind load).

3. STRUCTURAL ANALYSIS

Structural analysis principle and verification of strength.

Design resistance of structural parts evaluated in accordance with the formula (EN 13814:2004, 5.4.1 + EN 13814:2004, 5.6.2):

$$R_d = \frac{R_k}{\gamma_M} = \frac{355}{1.1} = 322MPa$$

R_d – design value of material properties; R_k – characteristic value of material properties ($R_k = 355MPa$);

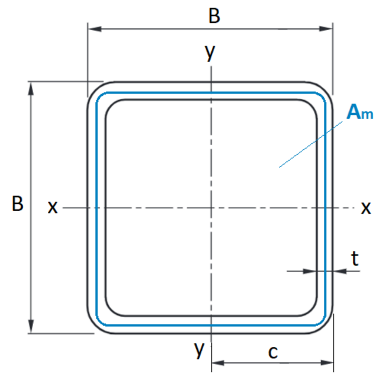
One of the main part is support pole on which screen is attached. The pole is 6000 mm long square tube that has cross-section 300 x 300 x 6.0 mm (Fig. 3).

Maximum bending stress acting on pole:

$$\sigma_{b,max,1} = \frac{F_{w1} \cdot (z_e - z_t) \cdot c}{I} \cdot \gamma_Q$$

$$\sigma_{b,max,2} = \frac{(F_{w2} \cdot (z_e - z_t) \cdot \gamma_Q + G_{LED} \cdot x_{CG,LED} \cdot \gamma_G) \cdot c}{I}$$

I is the moment of inertia of the cross-sectional area $I = 1.02 \cdot 10^8\ mm^4$; c - perpendicular distance from the neutral axis to a point farthest away from the neutral axis, $c = 150$ mm.



3 Fig. Cross section of rectangular tube (pole to support LED screen)

The recommended value of the horizontal wind eccentricity is $\mathrm{e} = \pm 0{,}25\mathrm{b} = \pm 0{,}25 \cdot 7 = \pm 1.75$ m (EN 1991-1-4:2005, 7.4.3)

It gives torque moment $\mathrm{T}_w = F_w \cdot \mathrm{e} \cdot \gamma_Q$ which has influence to the strength of pole.

Average shear stress caused by torque moment:

$$\tau_{avg} = \frac{T}{2 \cdot t \cdot A_m}$$

A_m the mean area enclosed within the boundary of the centreline of the tube's thickness.

$$A_m = (B - t)^2$$

Maximum equivalent stress

$$\sigma_{ekv} = \sqrt{\sigma_b^2 + 3 \cdot \tau_{avg}^2}$$

The pole strength is sufficient and has safety factor:

$$SF_{pole} = \frac{R_d}{\sigma_{ekv}}$$

Results of stress analysis and strength evaluation presented in table 2

Table 2

Trailer	v_b,	G_{LED}	$x_{CG,LED}$	z_t	z_g	F_W	M_{p1}	M_{p2}	T_p	$\sigma_{b,2}$	τ_{avg}	$\sigma_{eqv,2}$	γ_{min}	SF_{pol2}
	m/s	kN	m	m	m	kN	kNm	kNm	kNm	MPa	MPa	MPa		
73x23	**18**	12.6	0.5	0.73	**2.9**	10.2	42.6	48.9	17.9	54.1	17.2	61.8	1.2	**5.2**
73x23	**19**	12.6	0.5	0.73	**2.9**	11.4	47.4	53.7	19.9	59.2	19.2	67.9	1.2	**4.8**
73x23	**20**	12.6	0.5	0.73	**2.9**	12.6	52.5	58.8	22.1	64.5	21.3	74.2	1.2	**4.3**
73x23	**20.7**	12.6	0.5	0.73	**2.9**	13.5	56.3	**62.6**	23.6	68.4	22.8	78.9	1.2	**4.1**
73x23	**27**	12.6	0.5	0.73	**2.9**	23.0	95,8	102.1	40.2	109.3	38.7	128.2	1.2	**2.5**
73x23	**18**	12.6	0.5	0.73	**1.9**	10.2	32.4	38.7	17.9	33.8	17.2	45.1	1.2	**7.2**
73x23	**19**	12.6	0.5	0.73	**1.9**	11.4	36	42.3	19.9	36.5	19.2	49.4	1.2	**6.5**
73x23	**20**	12.6	0.5	0.73	**1.9**	12.6	39.9	46.2	22.1	39.4	21.3	53.9	1.2	**6.0**
73x23	**20.7**	12.6	0.5	0.73	**1.9**	13.5	42.8	49.1	23.6	41.5	22.8	57.2	1.2	**5.6**

Safety of support pole is sufficient to withstand wind velocity up to 27 m/s.

Safety against overturning (EN 13814:2004, 5.5.1.2):

$M_{st} \geq \gamma \cdot M_k$

M_{st} is the stabilising moment value, M_k is the overturning moment value, γ is the safety factor

$\gamma = 1.2$

$M_{st} = G_{tot} \cdot b_L/2 \cdot \gamma_G$

$$M_k = F_W \cdot z_e \cdot \gamma_Q + G_{LED} \cdot x_{LED} \cdot \gamma_G$$

G gravity load; G_{LED} gravity load of LED screen and panel frame; γ_G=1.1; $\gamma_Q = 1.35$; b_L distance between supports; z_e reference height of wind force.

$$SF_{ovt} = \frac{M_{st}}{M_k}$$

Results of safety against overturning analysis presented in table 3

Table 3

Trailer	v_b,	G_{LED}	G_{tot}	$x_{CG,LED}$	z_t	z_g	z_e	q_b	F_W	M_{st}	M_{k1}	M_{k2}	γ_{min}	SF_{ovt1}	SF_{ovt2}
	m/s	kN	kN	m	m	m	m	N/m^2	kN	kNm	kNm	kNm			
73x23	**18**	12.6	35	0.5	0.73	**2.9**	4.9	203	10.2	94	68	74	1.2	**1.40**	**1.27**
73x23	**19**	12.6	35	0.5	0.73	**2.9**	4.9	226	11.4	94	75	82	1.2	**1.26**	**1.15**
73x23	**20**	12.6	35	0.5	0.73	**2.9**	4.9	250	12.6	94	83	90	1.2	**1.13**	**1.05**
73x23	**20.7**	12.6	35	0.5	0.73	**2.9**	4.9	268	13.5	94	89	96	1.2	**1.06**	**0.98**
73x23	**18**	12.6	35	0.5	0.73	**1.9**	3.9	203	10.2	94	54	61	1.2	**1.76**	**1.56**
73x23	**19**	12.6	35	0.5	0.73	**1.9**	3.9	226	11.4	94	60	67	1.2	**1.58**	**1.41**
73x23	**20**	12.6	35	0.5	0.73	**1.9**	3.9	250	12.6	94	66	73	1.2	**1.42**	**1.29**
73x23	**20.7**	12.6	35	0.5	0.73	**1.9**	3.9	268	13.5	94	71	78	1.2	**1.33**	**1.21**

When the wind velocity reaches 18m/s, the LED screen has to be lower 1 m down.

Safety against sliding (EN 13814:2004, 5.5.1.2):

$$\sum \gamma \cdot 0.7 \cdot \mu \cdot N_k \geq \sum \gamma \cdot H_k$$

N_k is the vertical load component $N_k = G_{tot}$; H_k is the horizontal load component $H_k = F_w$; μ - coefficient of friction (Fig. 4) (EN 13814:2004, 5.5.1.3).

Coefficients of friction μ

	Wood	Steel	Concrete
Wood	0,4	0,4	0,6
Steel	0,4	0,1	0,2
Concrete	0,6	0,2	0,5
Clay[a]	0,25	0,2	0,25
Loam[a]	0,4	0,2	0,4
Sand and gravel	0,65	0,2	0,65
[a] At least of stiff consistency in accordance with ENV 1997-1.			

Safety factor against sliding:

$$SF_{sld} = \frac{0.7 \cdot \mu \cdot G_{tot} \cdot \gamma_G}{F_w \cdot \gamma_Q}$$

Results of safety against sliding (using friction coefficient $\mu = 0.2$) presented in table 4

Table 4

Trailer	v_b,	z_g	G_{tot}	F_W	SF_{sld}	SF_{sld}
	m/s	m	kN	kN	$\mu = 0.2$ (steel/concrete)	$\mu = 0.5$ (wet ruber/concrete)
73x23	**10**	**2.9**	35	7.1	**1.24**	**3.11**
73x23	**15**	**2.9**	35	7.1	**0.55**	**1.38**
73x23	**16**	**2.9**	35	8.1	**0.49**	**1.21**
73x23	**17**	**2.9**	35	9.1	**0.43**	**1.08**
73x23	**18**	**2.9**	35	10.2	**0.38**	**0.96**
73x23	**19**	**2.9**	35	11.4	**0.34**	**0.86**
73x23	**20**	**2.9**	35	12.6	**0.31**	**0.78**
73x23	**20.7**	**2.9**	35	13.5	**0.29**	**0.73**

Safety against sliding is not sufficient when the basic wind velocity is greater >10 m/s. In this case the ground anchorages has to be used.

Bolts (EN 13814:2004, 5.6.4).

Bolts and Nuts has minimum 8.8 quality. Important place is joint between pole and the trailer frame.

When the wind speed is 20.7m/s, the bending moment acting in the pole connection to the trailer frame is 62.6 kNm. This leads the $F_{bolt} = 31\ kN$ of axial force per one M16 bolt.

Design tensile force $N_{R,d} = 0.7 \cdot F_v = 0.7 \cdot 71 = \ 49\ kN$

$$SF_{bolt} = \frac{0.7 \cdot F_v}{F_{bolt}} = \frac{0.7 \cdot 71}{31} = 1.6$$

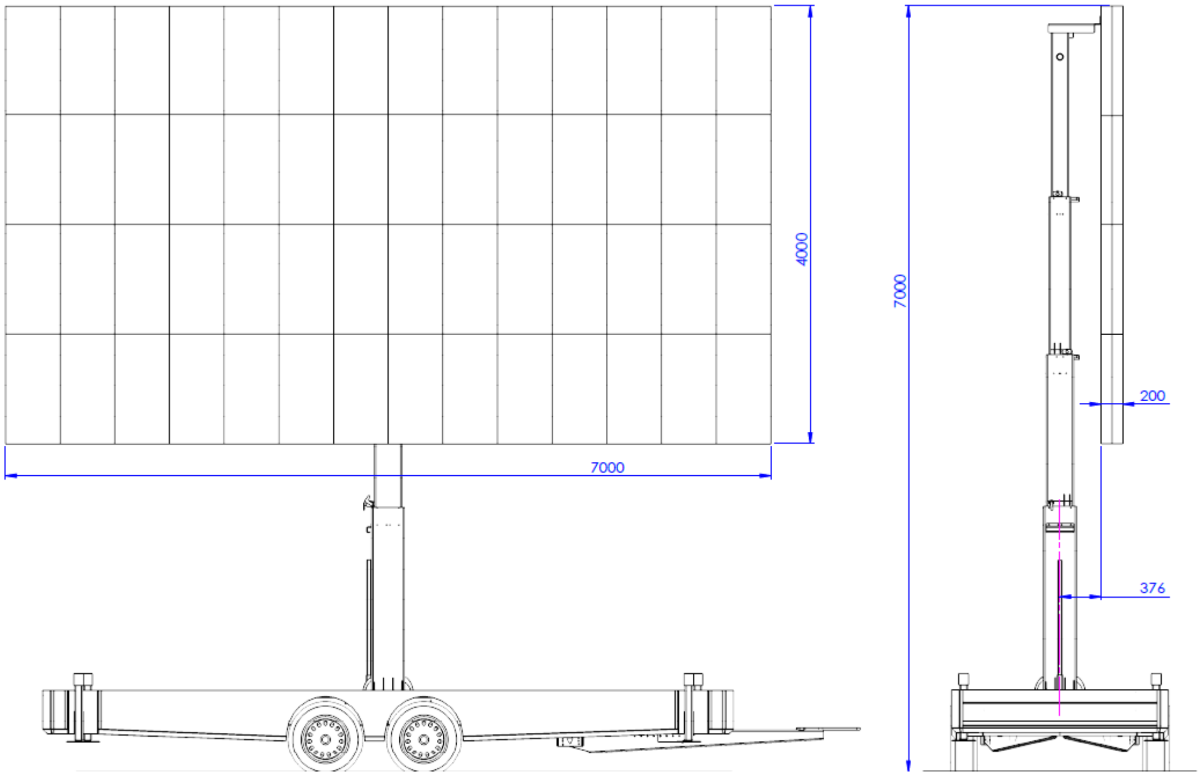
Safety of bolts connecting pole and the trailer frame are sufficient to withstand wind velocity up to 20.7 m/s.

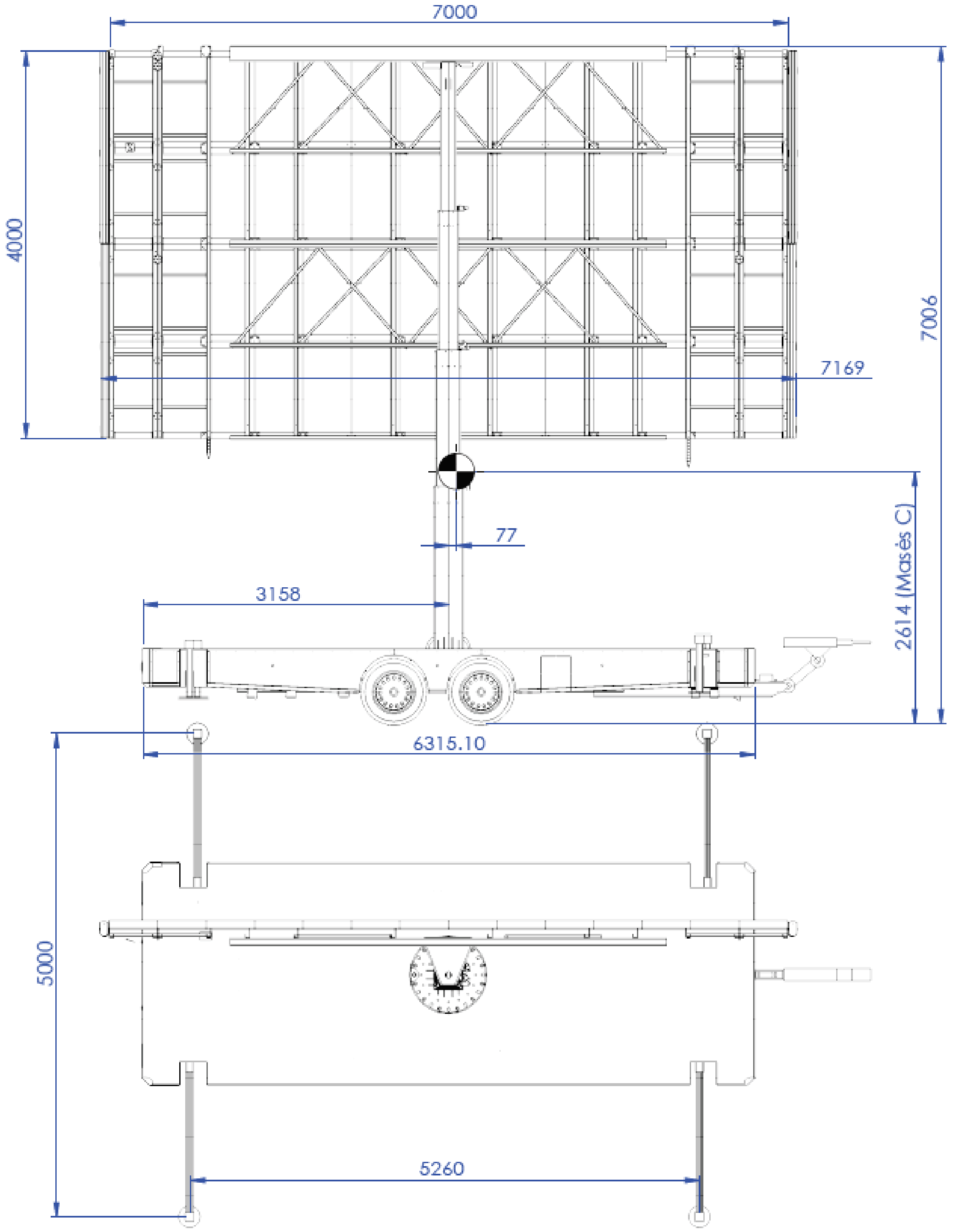
4. CONCLUSIONS

Structural analysis of trailer frame with LED screen comprise assessment of the operational safety under the wind loading shows:

- Strength of support pole is sufficient to withstand wind velocity up to 27 m/s;
- Safety against overturning is sufficient to withstand wind velocity up to 18 m/s, when the wind velocity rises over 18m/s, the LED screen has to be lower 1 m down;
- Safety against sliding is not sufficient when the basic wind velocity is greater >10 m/s. In this case the ground anchorages has to be used;
- Safety of bolts connecting pole and the trailer frame are sufficient to withstand wind velocity up to 20.7 m/s.

5. DRAWINGS

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