Come - Million!

Engineering Report

Burning Man 2018

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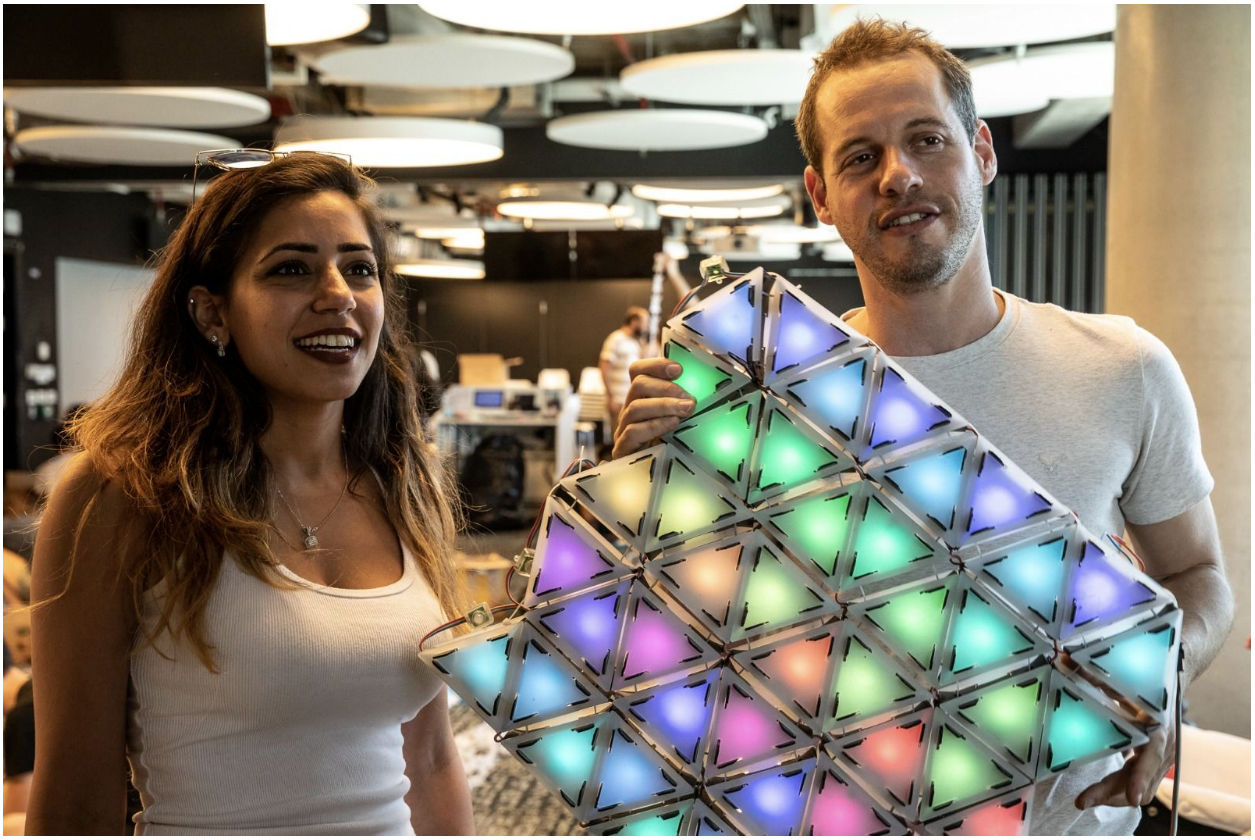
1. Introduction

Come - Million is a sculpture of a chameleon 19.3m long and 7.3m high. Its supporting structural skeleton made out steel pipes and rods welded together to form the outline of the piece.
The structural components will be connected together using bolt joints.

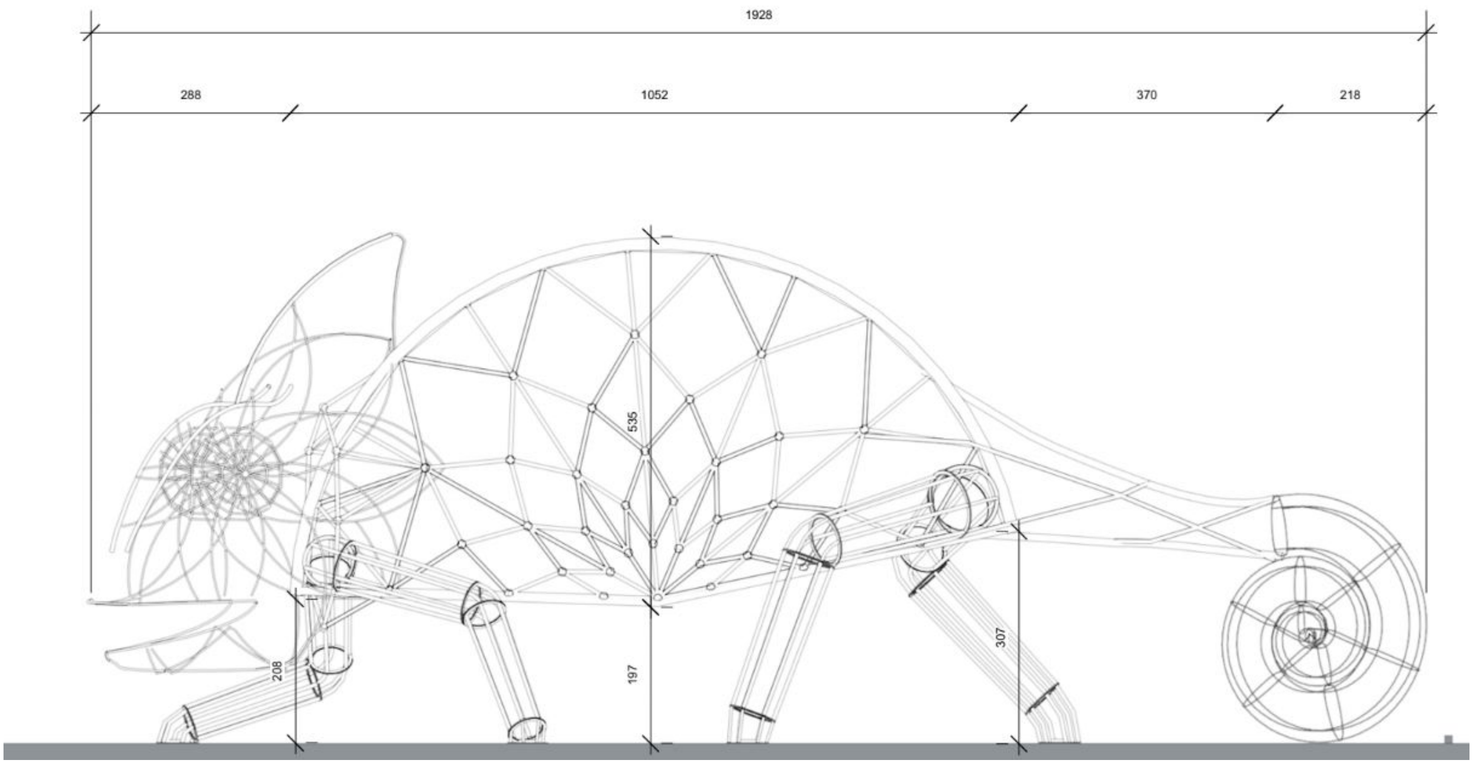
The chameleon skin made out of Plexiglas tiles which are diffusing the LED lights and are mounted to the structure with zip ties.

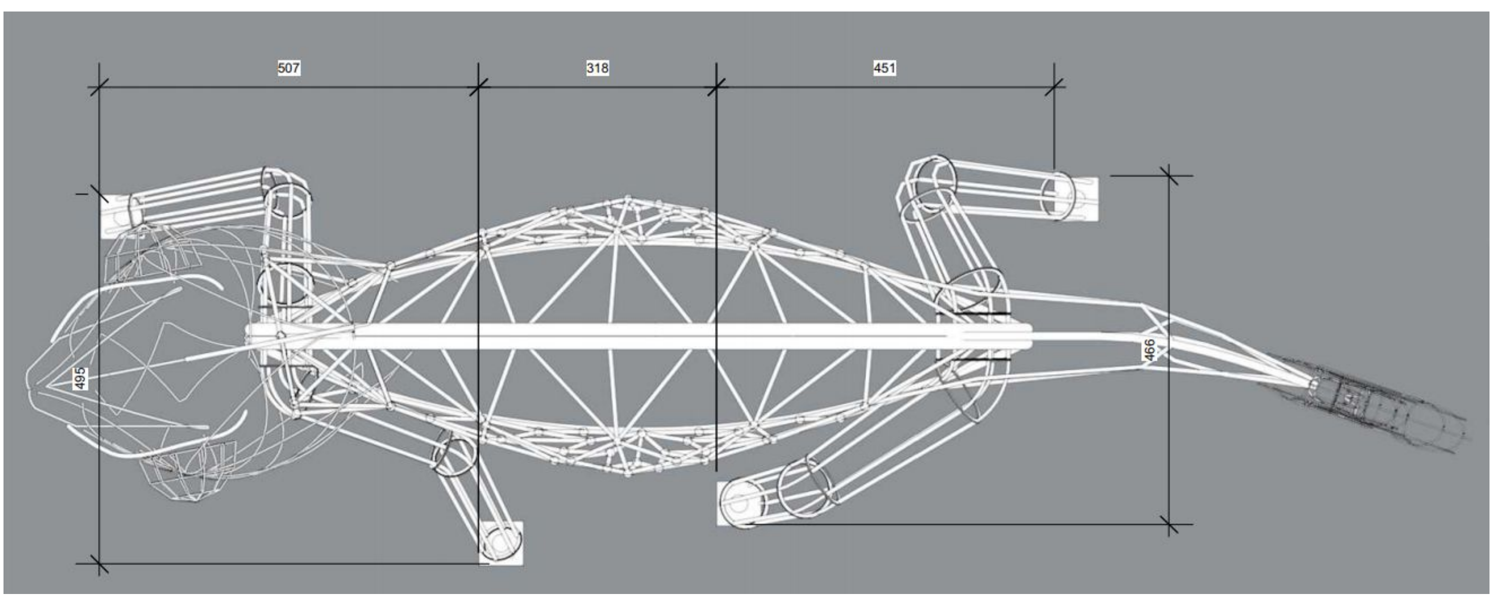


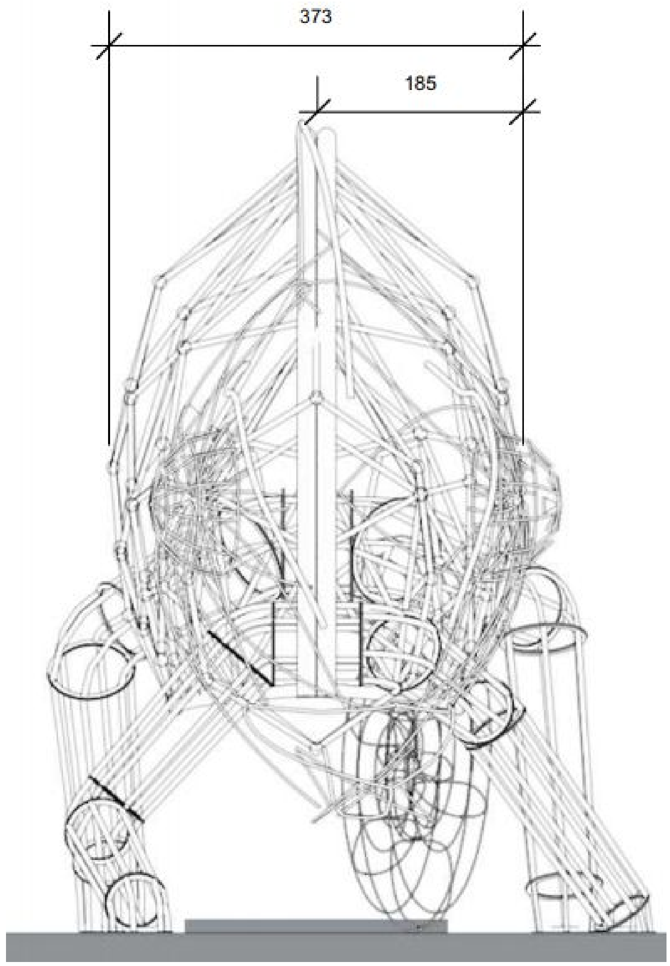
The structure is being anchored to the ground using 48” ground screw anchors in each leg’s base. The legs will be covered in a way that should prevent climbing on top the of structure although every component is capable of carrying the load in case of the no climbing restriction will be ignored.

2. Geometry and Materials

The dimensions of the structure are as the following in Centimeters:

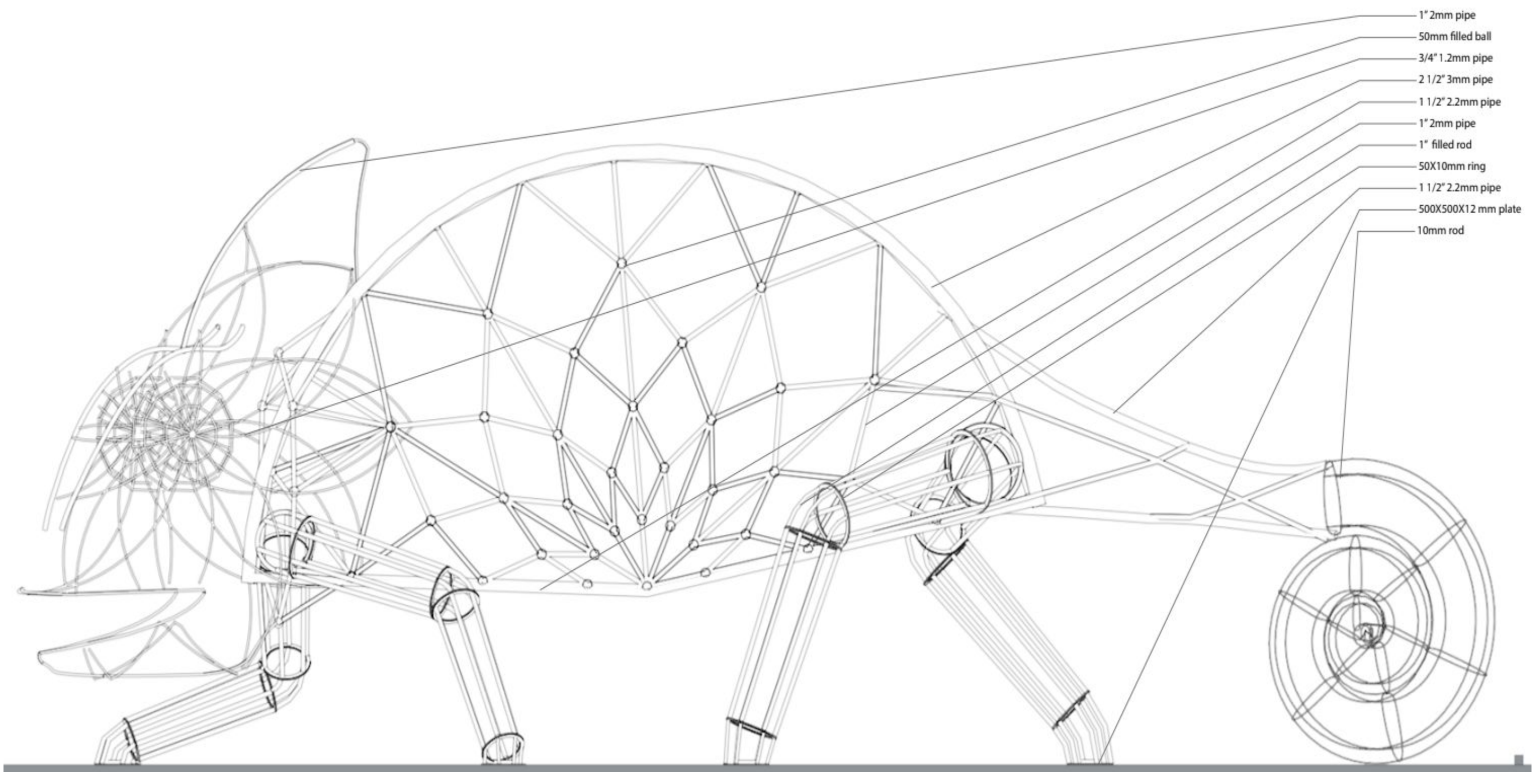






The structural members are made from FE510 grade steel with a design tensile strength of 350 MPa. All the bolts are made of standard 8.8 grade steel. The ground anchors were assumed to provide with at least 3000 lbs (1.35 metric tons) of tensile strength considering the Playa's soil.

The structural members are specified in the following drawing:



3. Loads

The structure sustains dead loads of self weight and additional skin load as well as wind load and potentially minor live load of a climbing person.

3.1 Wind Load

The force which applied to the structure by wind is calculated by the Israeli standard for wind loads IS414, equation 4.1 :

$$F_w = q_b \times c_e(z_e) \times c_s c_d \times c_f \times A_{ref} \quad (4.1)$$

$$q_b = \frac{v_b^2}{1.6}$$

v_b - Maximum wind speed. Calculated for 70 mph which are 30.5 m/s

$c_e z_e$ - Exposure coefficient considering that total height is 7.3m and open terrein, the value is **2.48**

$c_s\ c_d$ - Shape coefficient. since the total height is less than 15m, the value is **1.0**

c_f - Aerodynamics coefficient. given ration of $\frac{h}{b} = \frac{7.3}{19.3}$ = 0.37, value is **0.9**

A_{ref} - is the area on which the wind applies. According to the CAD model, the area on a single side face is **17.4 sqm**

Hence, the wind force applied to the structure when the wind is perpendicular would be:

$$F_w = 583.5 * 2.48 * 1 * 0.9 * 17.4 = 22,662.3\ [N] = 2.26\ [tons]$$

3.2 Dead Loads

The structures support its own gravitational of the steel framing and the tiles of the skin.

3.2.1 Skin tiles weight - each tile weight 2.2 kg. There would a total of 400 tiles mounted evenly on the body, tail and legs. A total of **880 kg** are distributed along the structure.

3.2.2 Steel framing weight:

Main body:
Joint steel balls (56 in total) - 9.5 kg
2.5” pipes (L=33m) - 120 kg
1” pipe (L=180m) - 237 kg
1.5” pipe (L=20.5m) - 44 kg
Total - 411 kg

Head:
1” pipe (L=87m) - 114 kg

Tail:
1.5” pipe (L=19.2m) - 39 kg
10mm rod (L=89m) - 54 kg
1” pipe (L=18.3m) - 24.8 kg
Total - 117.8kg

Legs:
1” rod (L=15.8m) - 60.8 kg
1.5” pipe (L=88.4m) - 158.4 kg
Steel rings t=10mm (21 in total) - ~45kg
Total - 263.8 kg

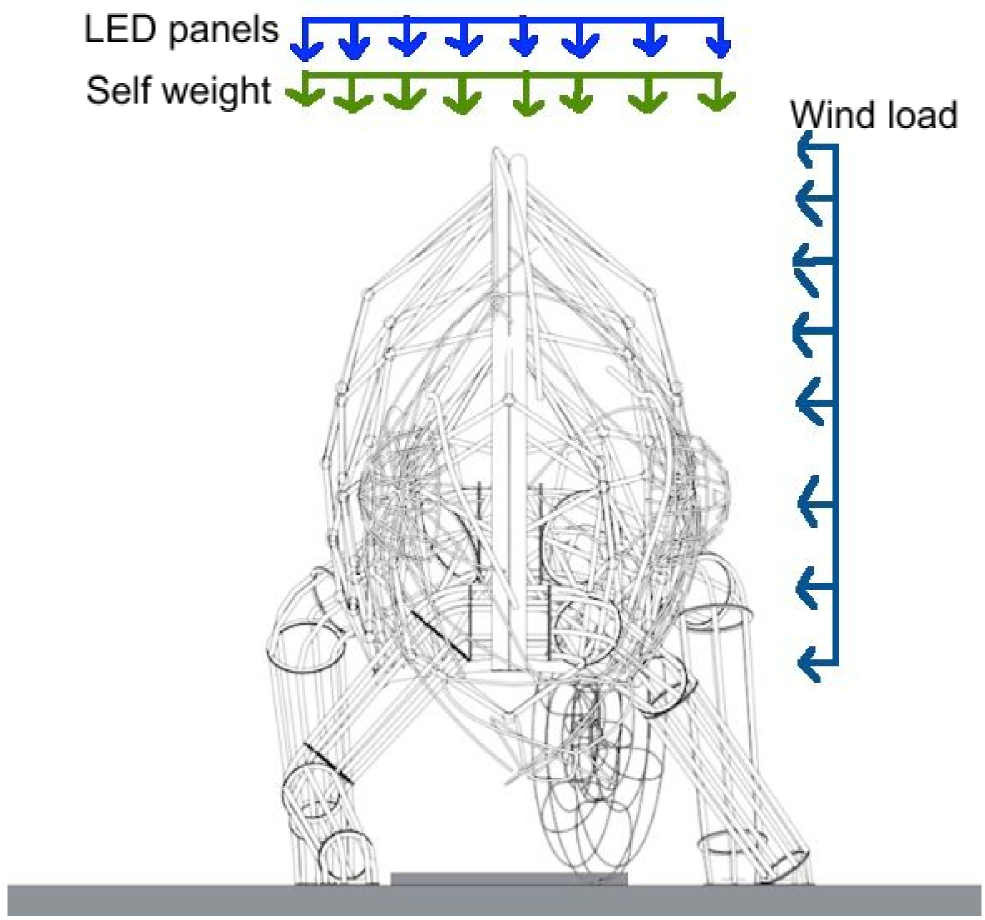
Total steel framing - **906.6 kg**

4. Static calculation and foundation

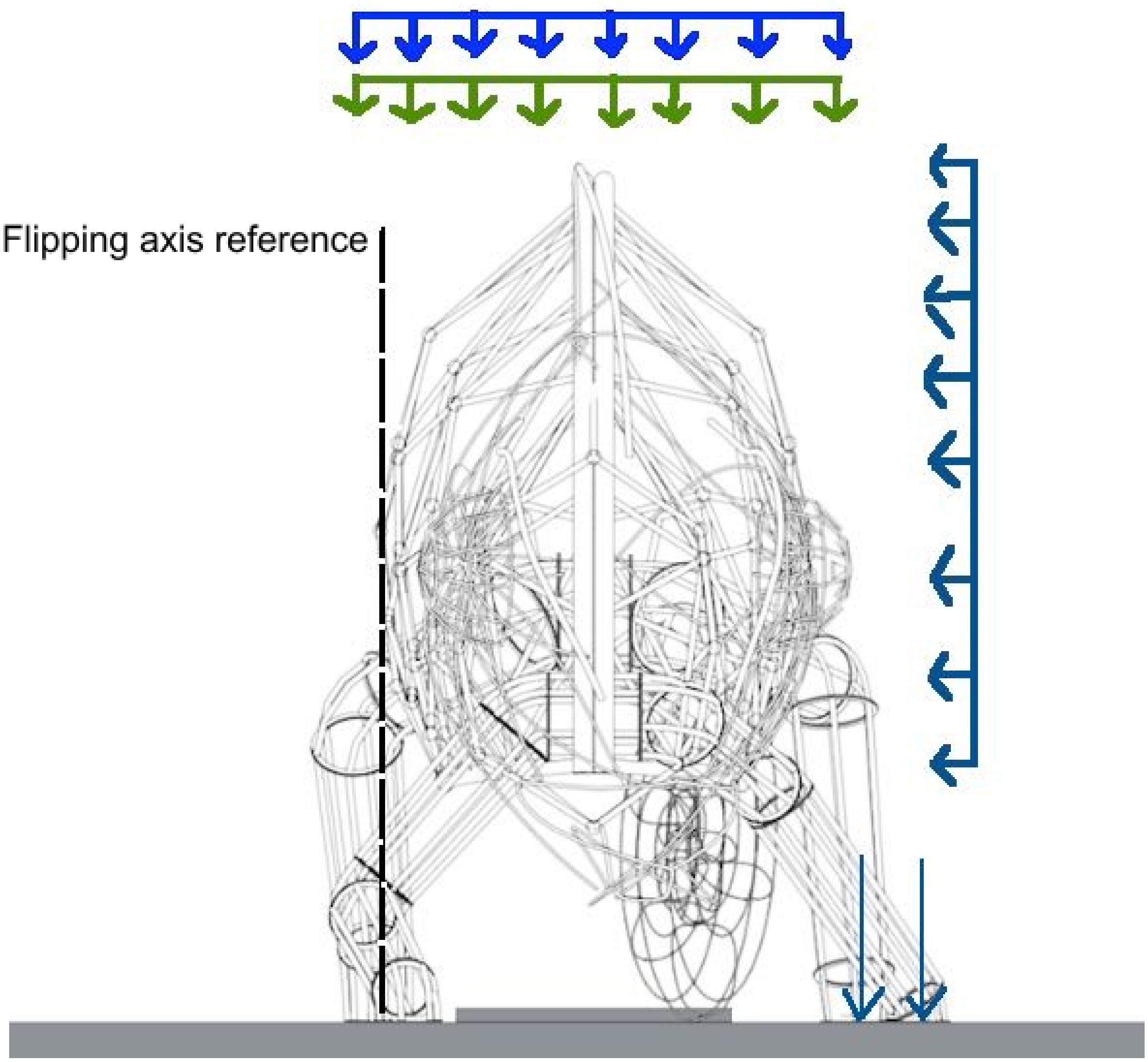
4.1 The structural calculations which were conducted are:

- General stability against flipping over
- Tensile and shear forces in the bolted joints

Loading scheme:



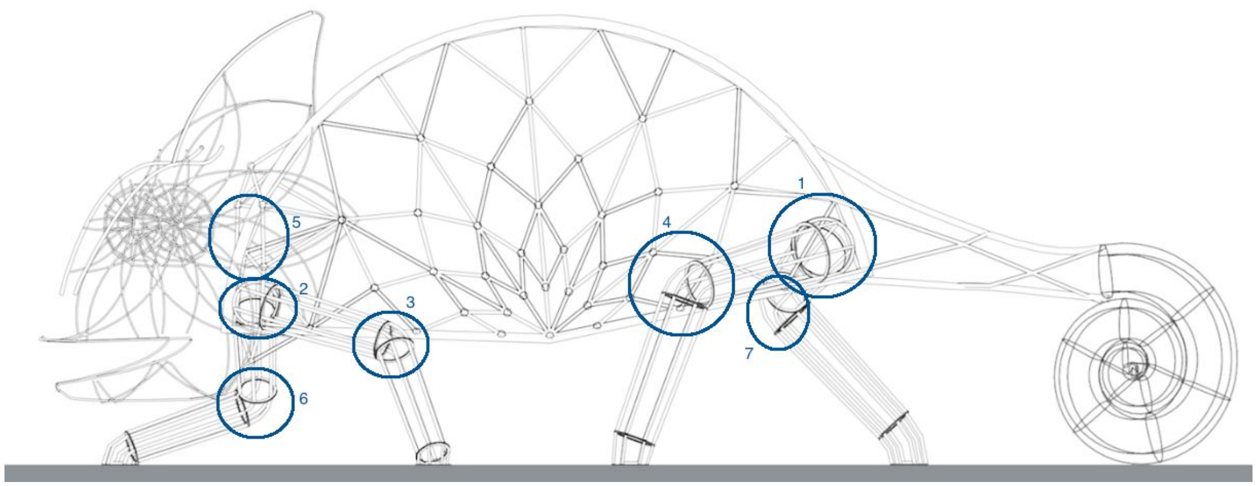
Flip over scheme inc. ground anchors (G.A's):



$$\Sigma M_0 = 1.18 * (906.6 + 880) - 5.15 * 2260 + 2G.A * 3.73 = 0$$
$$G.A = 1270\ kg < 1350\ kg \ -> OK$$

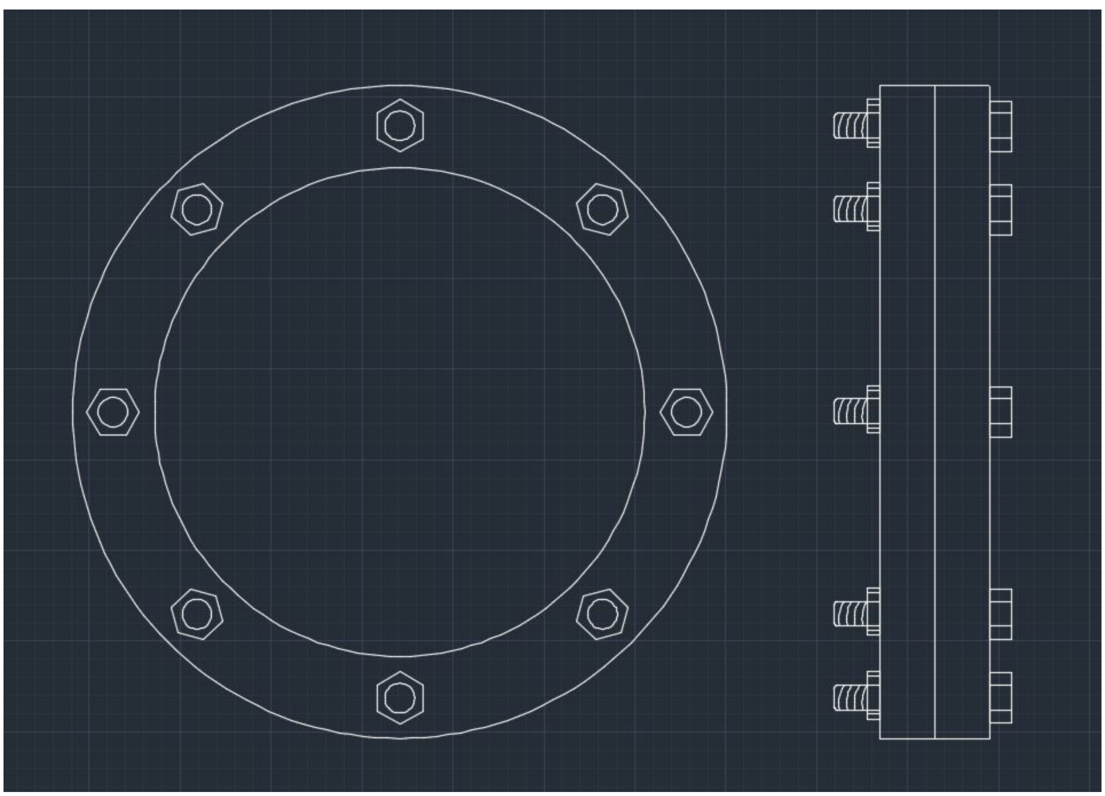
Under winds of 70 mph the structure is stable against flip over. These winds are not expected to last for extended period of time if at all. In case of a storm or peek point in wind speed at any given time, the structure should still remain stable.

Bolted joints capacity:



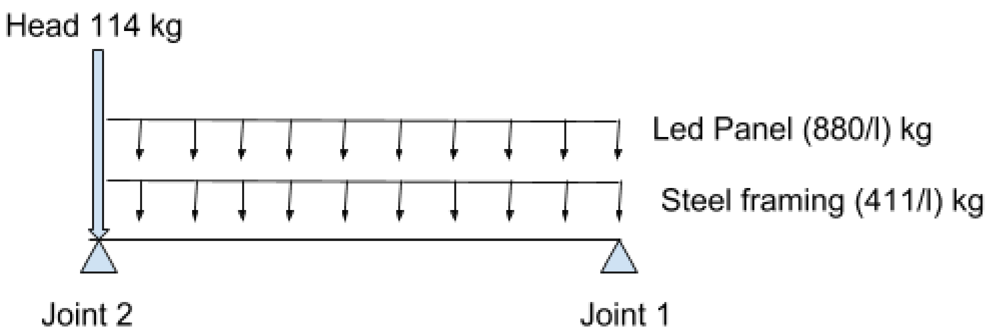
All of the structure's members are joined together using bolt joints of M10 screws. Joints 1 and 2 are connected using 15 screws, spread evenly around the steel ring, 10mm thick. Joints 3,6,4,7 are connected using 8 screws. Joint 5 holds the head to the body using steel plates at the jaw and cables on the top part.

Bolted ring joints:



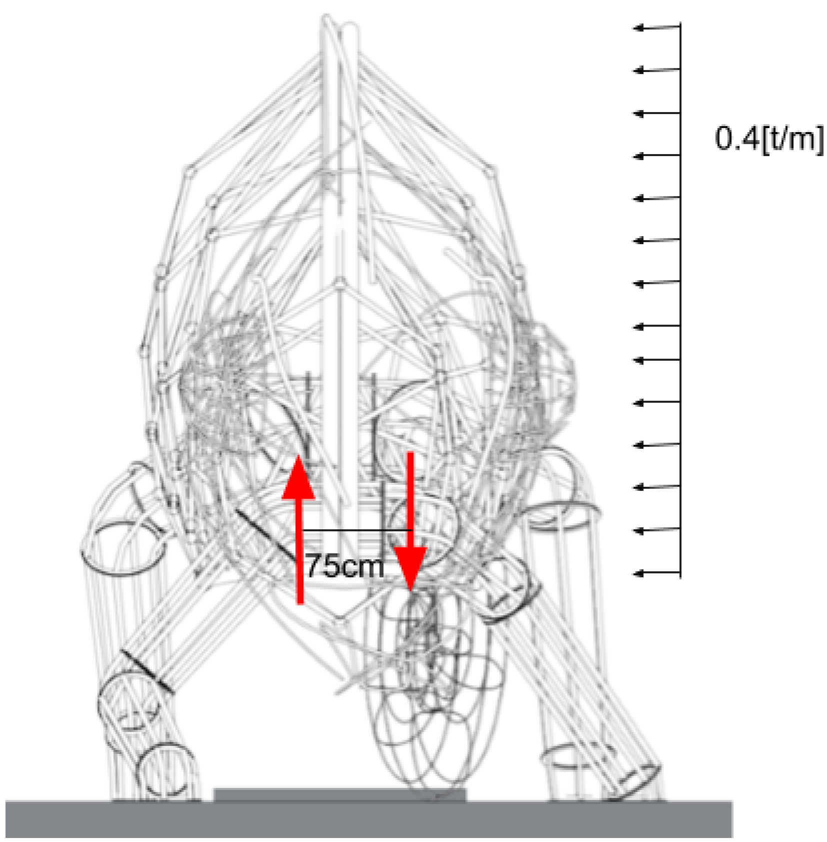
Shear force at joints 1,2:

Dead loads:



Joint 1 - $R_{d1} = \frac{880+411}{2}$ = 645 kg
Joint 2 - $R_{d2} = \frac{880+411}{2} + 114$ = 760 kg

Wind load shear reactions:



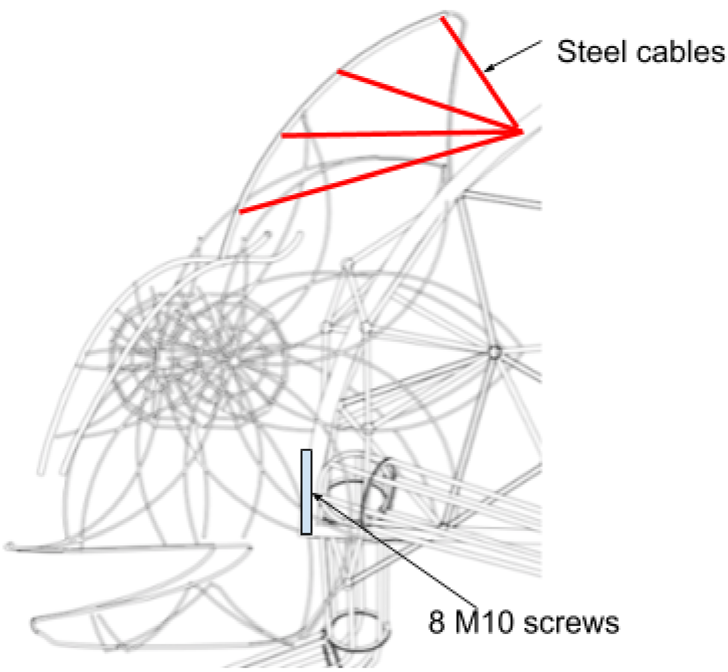
$R_w = \frac{M}{d}$, $M = \frac{ql^2}{2} = \frac{0.4*5.35^2}{2}$ =6.03[t*m] -> $R_w = \frac{6.03}{0.75} = 8.04\ [t]$

Max shear reaction occurs at joint 2 and equals to 8.8 tons. The critical joints are connected with 16 M10 screws with combined effective sectional area of 16*58= 928 [mm^2]. 8.8 grade steel remain elastic under 580 [MPa] of tensile stress and 350 [MPa] of shear stress.

$$R_{cap} = 928 * 350 * 10^{-4} = 32.5\ [ton] > 8.8[t] \ -> OK$$

Since the critical joints sustain the maximal load, all other joints has larger safety factor.

Joint 5



8 M10 screws are resisting the shear force applied by the head:

$$S_{Cap} = 8 * 58 * 350 * 10^{-4} = 16.24\ [t] >> 114\ kg$$

The steel cables acts as tensile reaction to the bending moment applied by the head.