Test Rig Adaptation for WT Measurements for OR&TP Configurations

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Abstract: *The need to test large models at maximum speed regimes close to 100 m/s, for which the aerodynamic forces and moments occurring on the model far exceed the measuring capability of the existing TEM external balance, made it necessary to design an alternative model support system installed outside the INCAS subsonic wind tunnel. This is the case of models included in the Clean Sky European programs GRA and SFWA ITD. The wingspan of these models is equal to the width of the test section. For these models, the pressure distributions on the model surface should be determined by pressure measurement through small orifices connected to scanning devices while the aerodynamic forces and moments will be obtained by integration of the pressure and shear stress distributions. To this purpose a model support system was designed which is not attached to the external balance but to the steel structure of the tunnel located outside the experimental room.*

Key Words: *wind tunnel testing, test section.*

1. INTRODUCTION

The measuring capacities of the existing TEM balance are the following:

- Lift: -200 Kgf to +700 Kgf
- Drag: -100 Kgf to +200 Kgf
- Side force: -200 Kgf to +200 Kgf
- Pitching moment: -110 Kgfm to +110 Kgfm
- Rolling moment: -110 Kgfm to +110 Kgfm
- Yawing moment: -110 Kgfm to +110 Kgfm

The maximum forces and moments occurring on the wing and flap for the 2D TURBO PROP wing model of the GRA program are shown in the table below:

Loads	C0	C1=C2=C3		C4	
	Wing	Wing	Flap	Wing	Flap
F_Z (N)	±18000	±22000	±1500	±22000	±2000
F_X (N)	2000	1100	1500	1100	1500
M_Y (Nm)	-3500	-4000	-1000	-4000	-1500

It is obvious that the model cannot be installed on the existing TEM external balance.

For testing at angles of attack between -10° and +10° and/at a speed of Vmax = 90 m/s an attachment outside the wind tunnel capable to withstand the imposed loads must be designed. The model will be installed “wall-to-wall” and no pylons will be installed inside the test section. Tests will be performed at selected fixed α values, in “step by step” mode.

The model will be installed in a horizontal position between the two test section lateral walls, resulting in a nominal model span of 2,5 m.

2. DESCRIPTION OF THE STRUCTURE

The designed steel structure is attached to the existing pillars and frames of the wind tunnel. The pillars are embedded in concrete and located upstream and downstream respectively, on both sides of the experimental test section. The axial distance between these frames is 4600 mm and the transverse distance is about 2800 mm. The pillars are made of standardized 160 UNP profiles, joined to form I profiles and they actually support the steel structure that supports the tunnel walls along the test section. The new structure consists of two removable symmetrical assemblies, one on each side of the tunnel. Each of the two assemblies consists of two horizontal beams made out of 160 UNP profiles, joined together by four L-shape L100x75x8 profiles, which form two vertical structures, positioned at the balance centerline. Each of these structures contains an internal frame including a rectangular plate of size 16x700x480 mm, which supports the bearing housing and the incidence mechanism components.

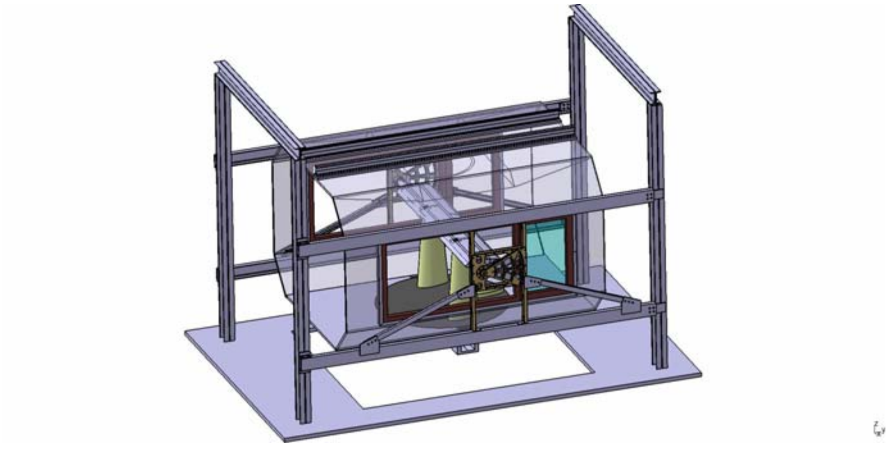

Fig. 1 Assembly structure and TURBO PROP wing with test section and the balance

This mechanism provides angles of attack in the - 15º ÷ + 25° range, in 1° steps. The structures containing the left and right bearing units are joined to the lower horizontal beams through two bracing attached by means of 2x6 M12 screws. These are prestressed, high-strength bolts, according to the existing standards STAS 8796/1-80 and STAS 8796/0-77 (mechanical group 8.8 or 10.9). Nuts and washers shall be used which are appropriate to high strength bolts for group 8.8 or 10.9, respectively.

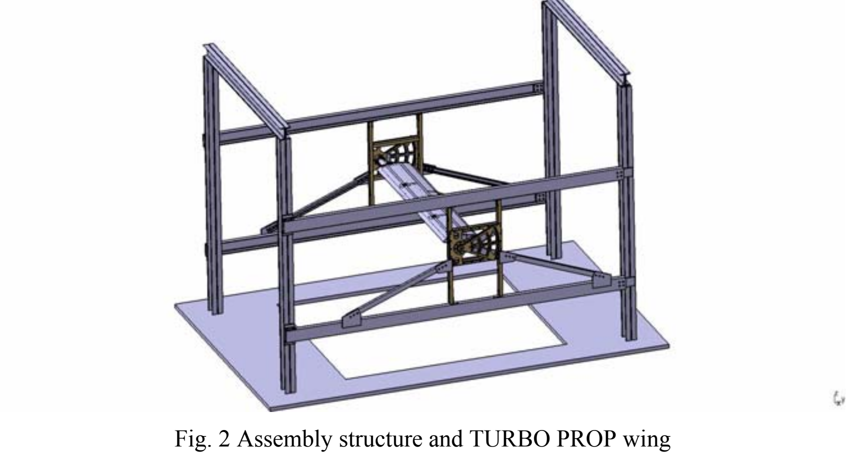

Fig. 2 Assembly structure and TURBO PROP wing

The transmission of efforts between components is done by the forces of friction developed between surfaces of these elements in contact under load, within the limits of friction determined by the pretension of these screws.

The screws are made of steel of high strength, obtained by appropriate heat treatment. Contact surfaces of combining elements are processed to achieve the friction coefficient adopted in joints calculation.

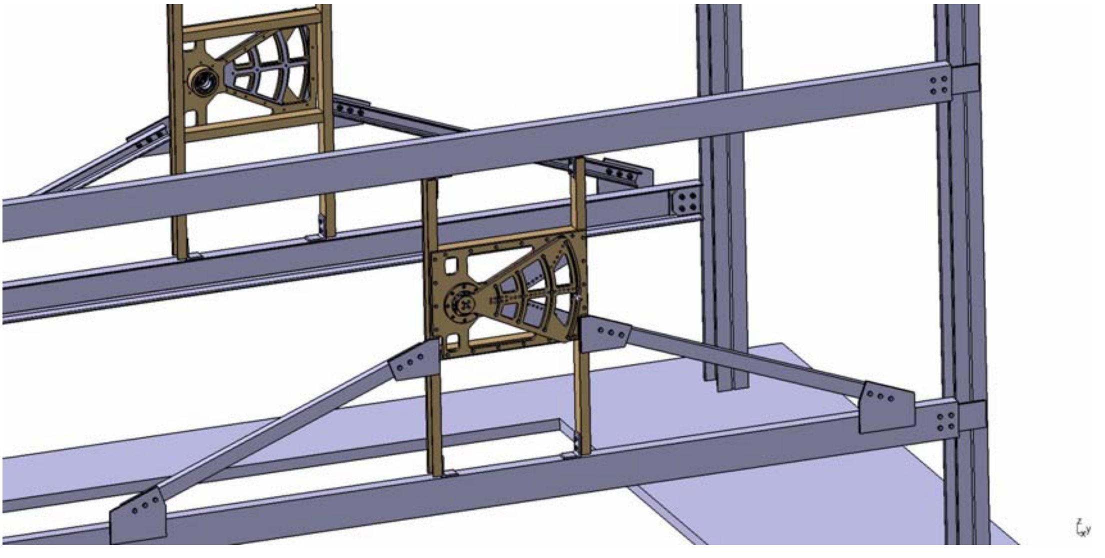

Fig. 3 shows the subassembly structure, with appropriate indexing mechanism.

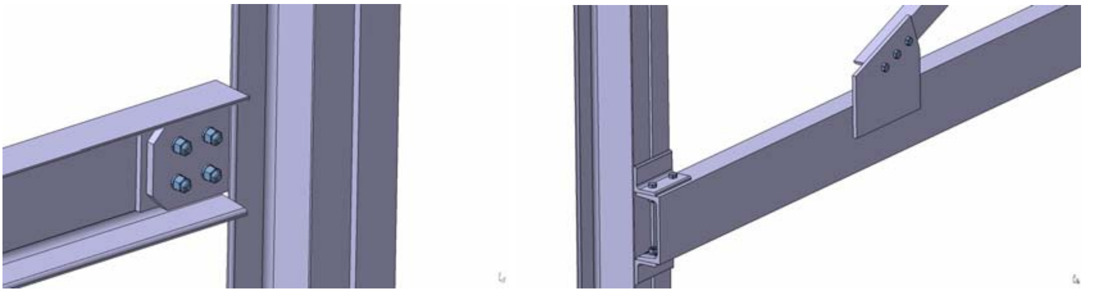

Fig. 4 Joints of horizontal beam

Self-aligning ball bearings with unsealed cylindrical bore are mounted inside these bearing housings, allowing the model to rotate at the desired angles of incidence.

The main dimensions for these ball bearings are:

- d= 60 mm
- D = 110 mm
- B = 28 mm
- Basic load ratings:
    - dynamic: C = 48,8 KN
    - static: C_0 = 17 KN
- Fatigue load limit: P_u = 0,88 KN
- Designation: 2212ETN9

The rotation shaft at the tips of the model ends with a rectangular piece that attaches the mobile indexing plate of the pitching mechanism.

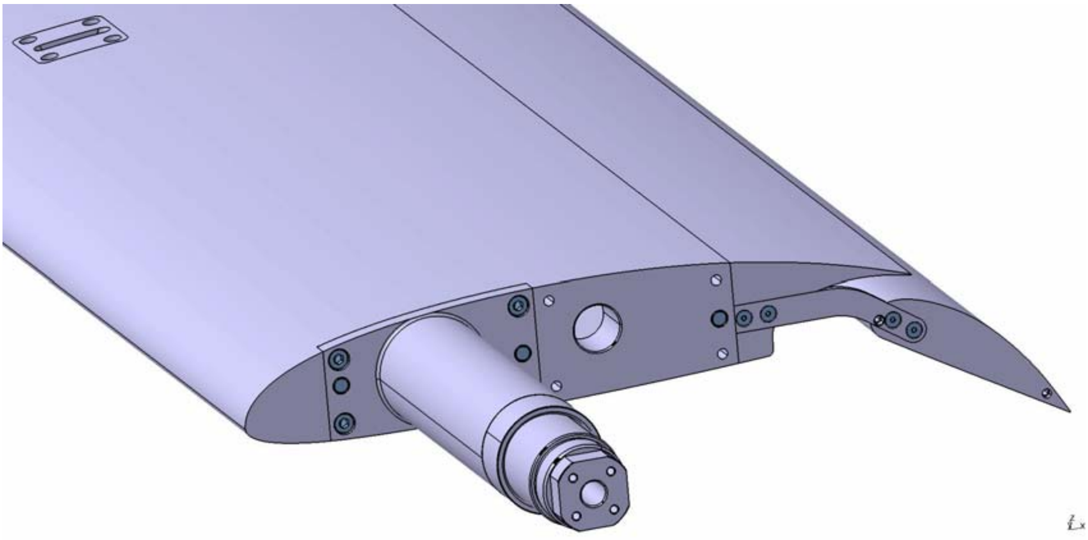

Fig. 5 The rotation axis at the wing tips

Ø10 mm holes are provided on the indexing mobile plate for indexing at the required angle of incidence, together with channels for attachment to the indexing mechanism. Indexing is done only on the left incidence mechanism, the right incidence mechanism ensuring only the attachment of the model.

Fig. 6 Plates which provide the rotation of the wing

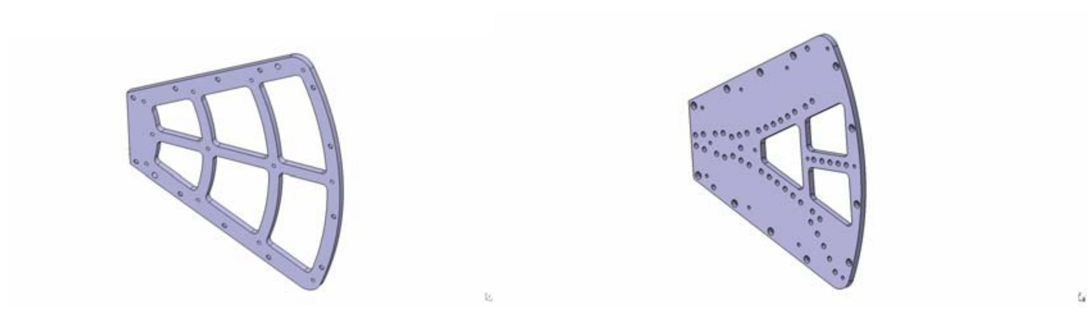

Fig. 7 Fixed indexing plates

The Ø10 mm holes are placed on concentric arcs in the range -15° ÷ + 25°, in 1° steps.

Special attention should be paid to align the two bearing boxes, so that they are horizontal and collinear.

This can be done with clinometers, or line laser.

A 2D representation of the unit bearing that fits the model is shown in the figure below.

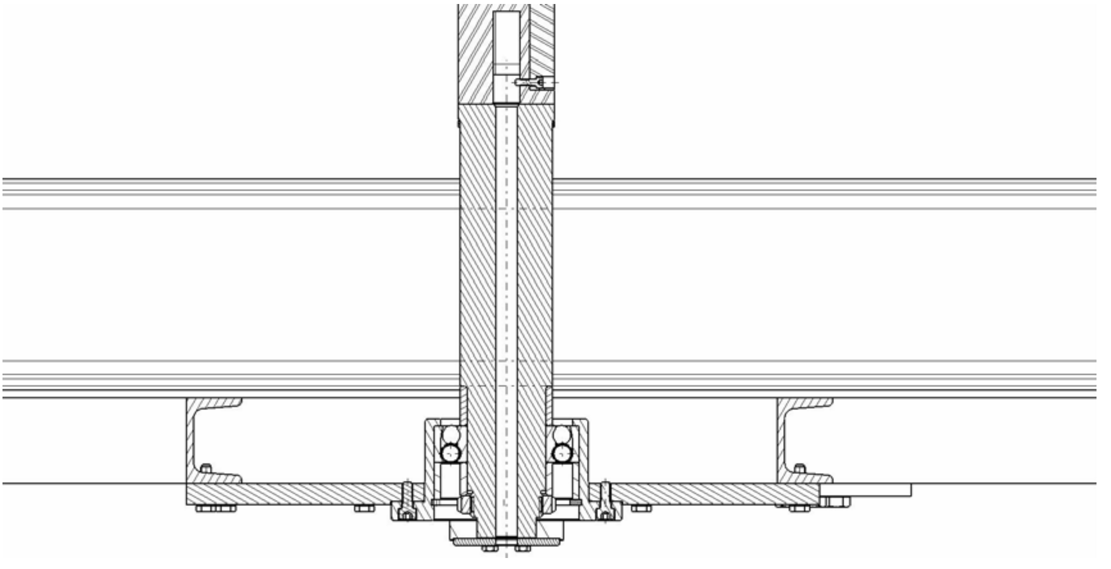

Fig. 8

3. CALCULATIONS TO VERIFY THE WING SHAFT RESISTANCE

If we consider that the wing is embedded at both ends and has a force with a value of F = 2400 daN concentrated at its center, the reaction forces are $V_1 = V_2 = 1200$ daN, bending moments are:

$$M_{1x} = M_{2x} = \frac{F * l}{8} = 900 \text{ daNm – after x direction}$$

In addition, at the middle M_F = - 900 daNm, where l = 3000 mm is the distance between the units bearing. A concentrated force that gives worst-case calculation was considered.

$$\tau_f = \frac{\sqrt{V_1^2 + 0,25 * F_X^2}}{A} = \frac{\sqrt{V_1^2 + 0,25 * F_X^2}}{\frac{\pi}{4}\left(D^2 - d^2\right)} = \frac{\sqrt{1200^2 + 0,25 * 260^2}}{\frac{\pi}{4}\left(60^2 - 16^2\right)} = 0,4596 daN / mm^2$$

$$\tau_t = \frac{M_Y}{W_p} = \frac{M_Y}{\frac{\pi\left(D^4 - d^4\right)}{16 * D}} = \frac{550 * 1000}{\frac{\pi\left(60^4 - 16^4\right)}{16 * 60}} = 13,034 daN / mm^2$$

$$\tau_{tot} = \tau_f + \tau_t = 13,4936 daN / mm^2$$

$$\sigma_{ix} = \frac{M_{1x}}{W_z} = \frac{M_{1x}}{\frac{\pi\left(D^4 - d^4\right)}{32 * D}} = \frac{900 * 1000}{\frac{\pi\left(60^4 - 16^4\right)}{32 * 60}} = 42,657 daN / mm^2$$

$$M_{1z} = M_{2z} = \frac{F_x * l}{2 * 8} = \frac{260 * 3000}{2 * 8} = 48{,}75 daNm$$

$$\sigma_{iz} = \frac{M_{1z}}{W_z} = \frac{48{,}75 * 1000}{21098{,}517} = 2{,}31 daN / mm^2$$

$$\sigma_i = \sigma_{ix} + \sigma_{iz} = 44{,}967 daN / mm^2$$

$$\sigma_{ech} = \sqrt{\sigma_i^2 + 4 * \tau_{tot}^2} = \sqrt{44{,}967^2 + 4 * 13{,}4936^2} = 52{,}443 daN / mm^2$$

The shaft is made of 1.7784.6, a high strength hardened tempered steel with R_m=1800-2000 MPa.

$$c = \frac{R_m}{\sigma_{ech}} = \frac{180}{52{,}443} = 3{,}432$$

4. CALCULATIONS TO VERIFY THE STRUCTURAL RESISTANCE

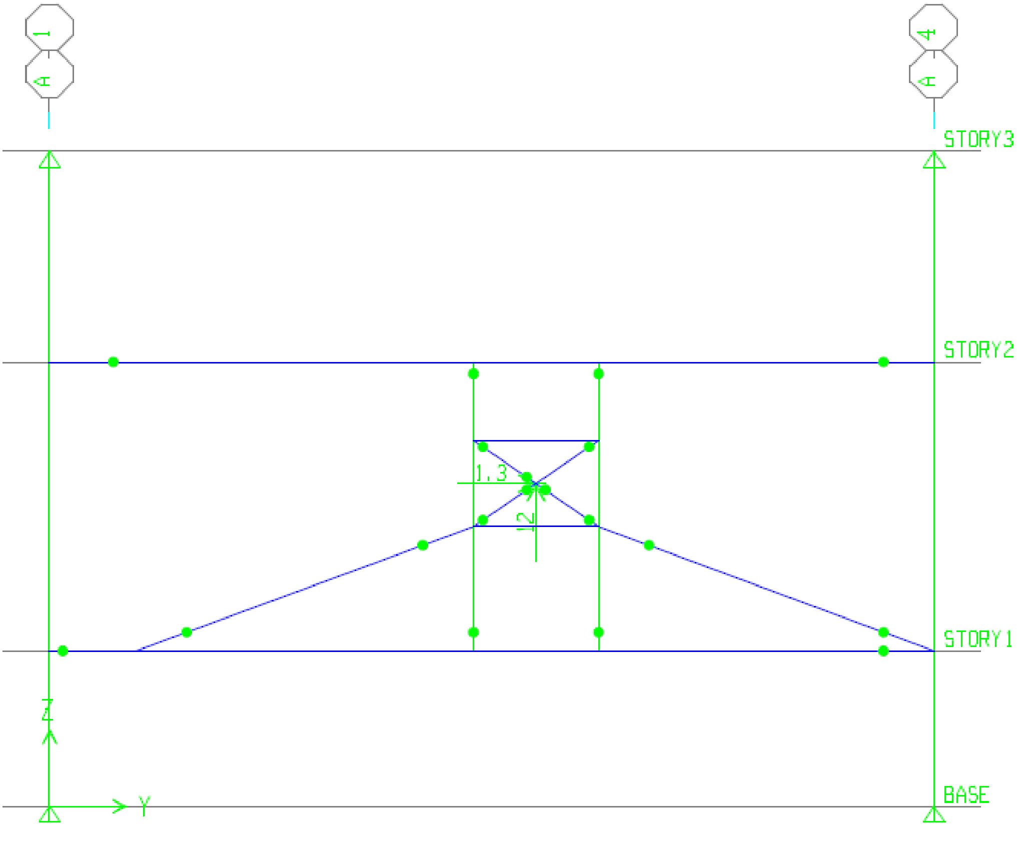

Fig. 9

The loads are represented in Fig. 9.
They are: normal force F_Z = 12 KN and axial force F_X = 1,3 KN.
Diagrams of axial and shear forces are given in Fig. 10 and Fig. 11.

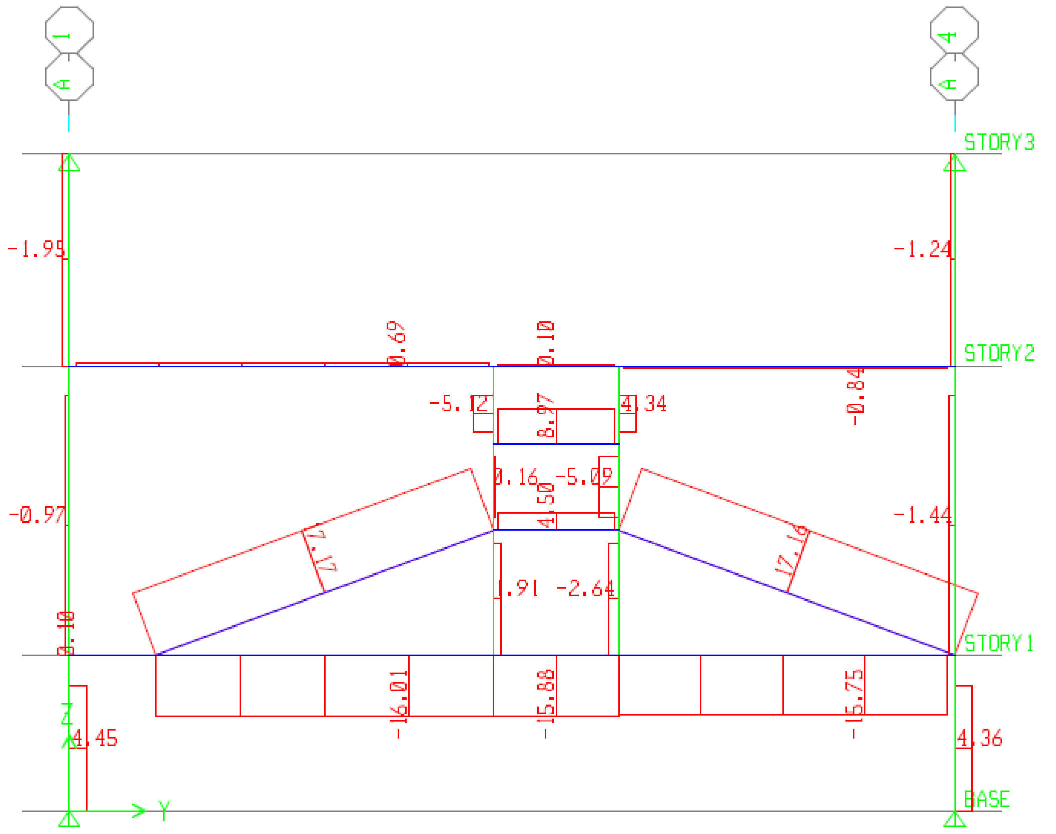

Fig. 10

For the bracing, the stretching efforts are:

$$\sigma_t = \frac{N}{A} = \frac{17{,}17}{9{,}03 * 100} = 0{,}019 KN / mm^2 = 1{,}9 daN / mm^2$$

For the lower horizontal beam the compressive stress is:

$$\sigma_t = \frac{N}{A} = \frac{16{,}01}{24 * 100} = 0{,}667 daN / mm^2$$

Because of the bracings, the efforts due to the moments are negligible.
The OL 37 steel has the following mechanical characteristics:

- tensile strength, ultimate σ_r = 36,3…44,1 daN/mm^2;
- tensile strength, yield σ_c = 20,6...23,5 daN/mm^2;
- elongation at break δ_5 = 26…25%;

The admissible resistance is:

$$\sigma_a = \frac{\sigma_c}{c_c} = \frac{20{,}6}{1{,}5} = 13{,}73 daN / mm^2$$

value that covers effective efforts in beams.

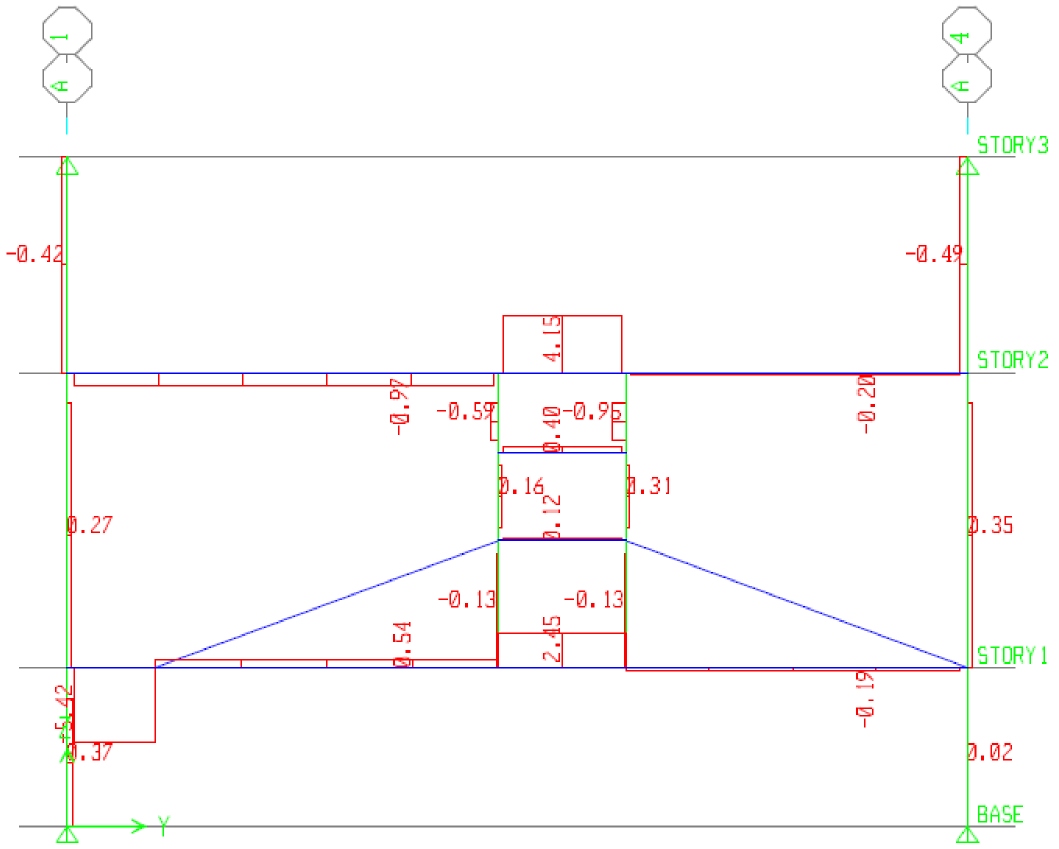

Fig. 11

5. CONCLUSION

Such a structure was thought to be cheap and easy to make and install. Moreover, it does not require a long execution time.

It should be noted that with an electric or hydraulic drive through a certain mechanism (ball screw-nut, pinion-quadrant, worm-worm wheel, etc.), the necessary components must be designed to fit on the rectangular plate and bearing housings, in order to ensure the rotation of 2D wing.

REFERENCES

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