Technical Report

FINHA 150 Series Building Structural Calculations

For the central regions of Russia

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INTRODUCTION

This calculation was performed to confirm that the strength and stability characteristics of the FINHA-A100 building series with connectors comply with the requirements of building codes SP 64.13330.2017 “SNiP II-25-80. Wooden Structures.” The calculation is carried out for loads corresponding to the operating conditions of buildings in the central regions of Russia:

- Snow zone IV ;
- Wind zone II, terrain type C;
- seismicity of the construction site is less than 6 points;

Objective:

- Determination of the maximum frame dimensions for which the safety factor is at least 1.0.

1. INITIAL DATA FOR CALCULATION

1.1 General description

A general view of the FINHA 150 series frames and buildings based on them is shown in Figs. 1–12.

The building frame is assembled from transverse frames made of wooden beams, which are connected to each other via connectors, and longitudinal beams. The frame is installed on the grillage beams, which are also made of wood.

Frame beams are made from 45x140 mm section boards. Frame pitch L=625 mm.

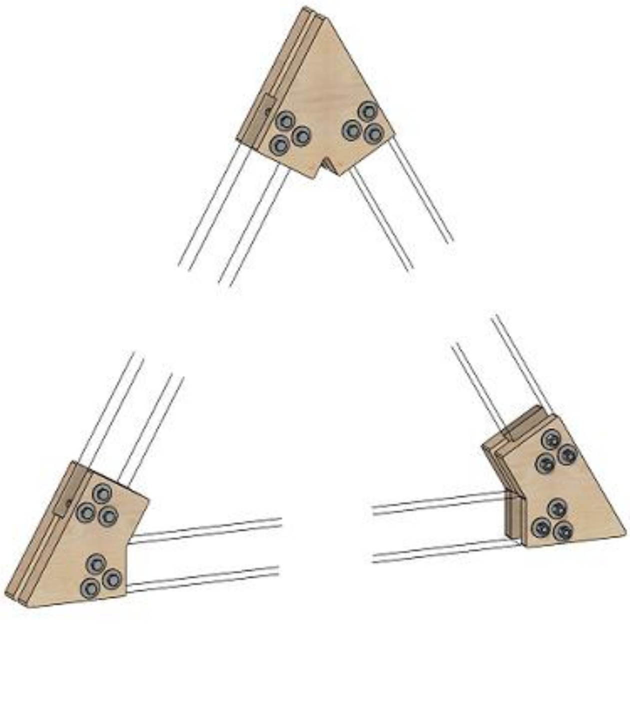

Fig. 1. Building connectors FINHA-A150

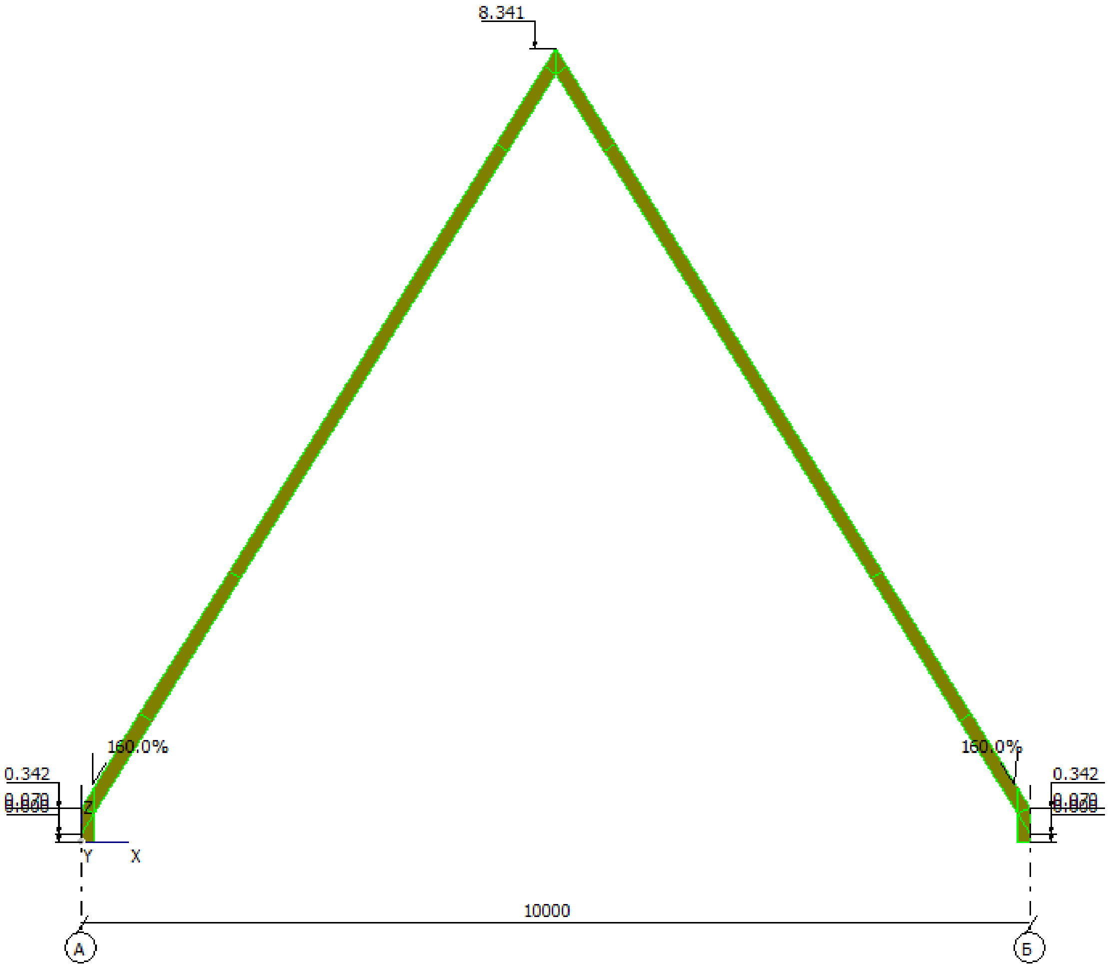

Fig. 2. FINHA-A150 building frame

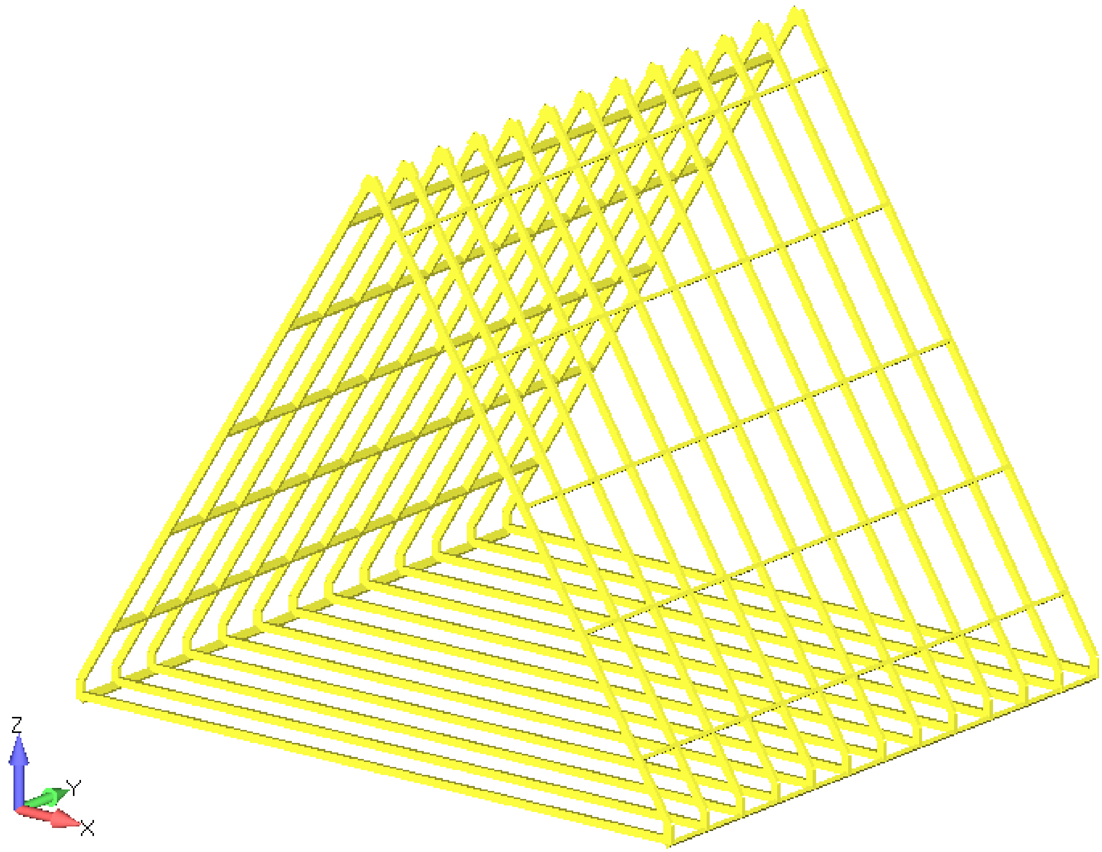

Fig. 3. General view of the FINHA-A 150 building frame, 10 meters wide

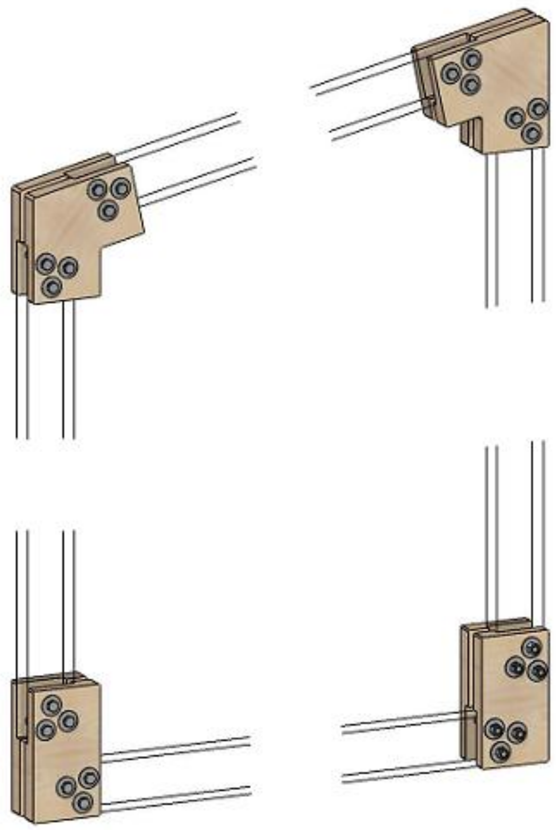

Fig. 4. Building connectors FINHA-P150L

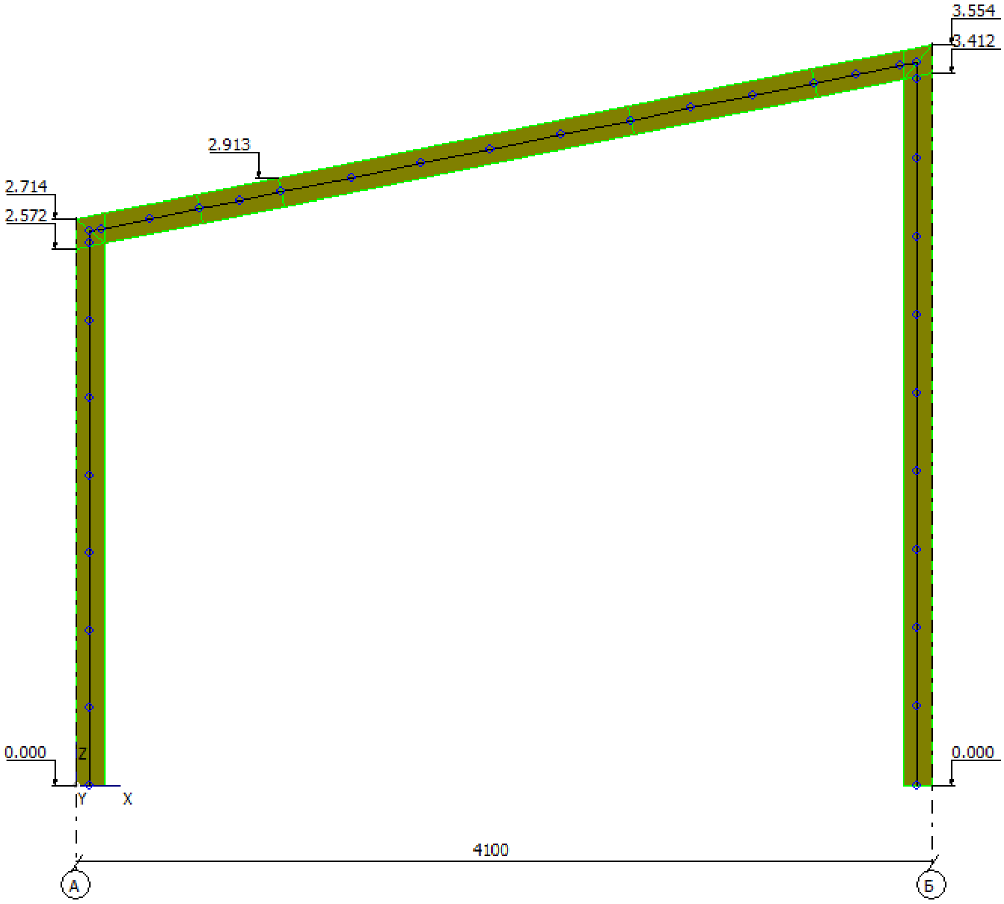

Fig. 5. FINHA-P150L building frame

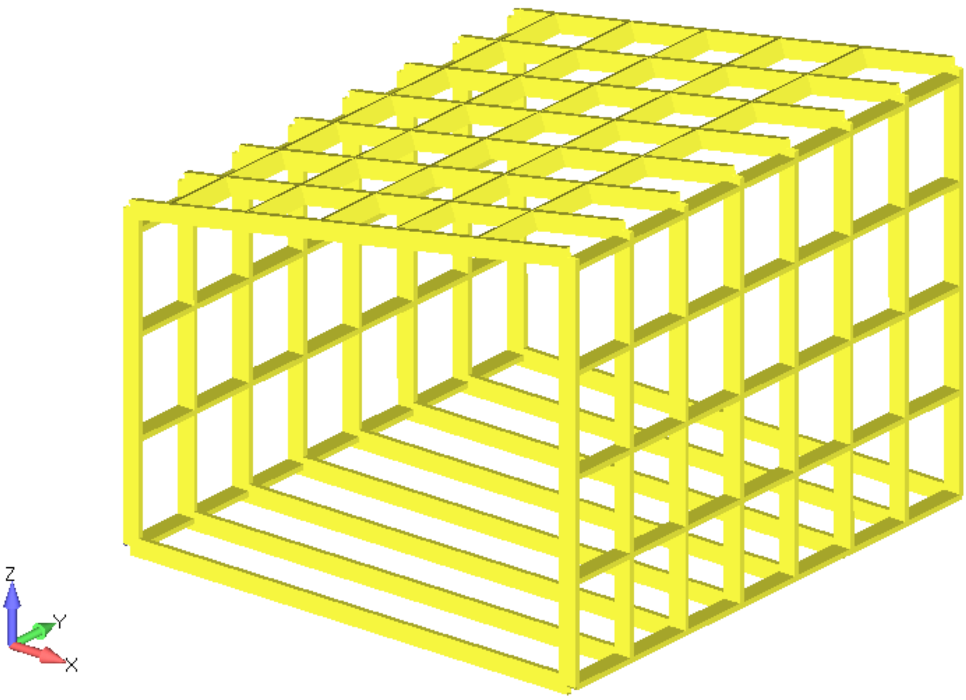

Fig. 6. General view of the FINHA-P150L shed-roof building frame, 4.1 meters wide

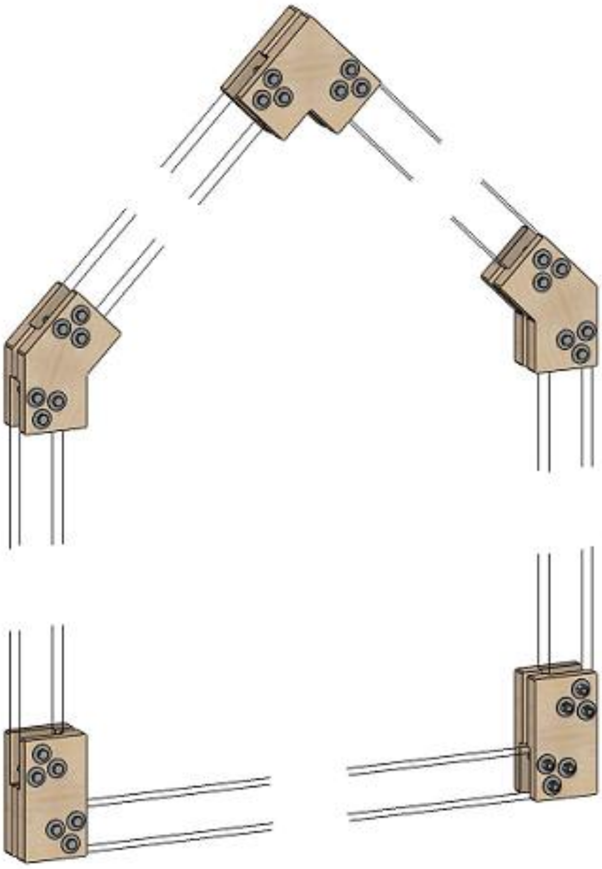

Fig. 7. Building connectors FINHA-V150

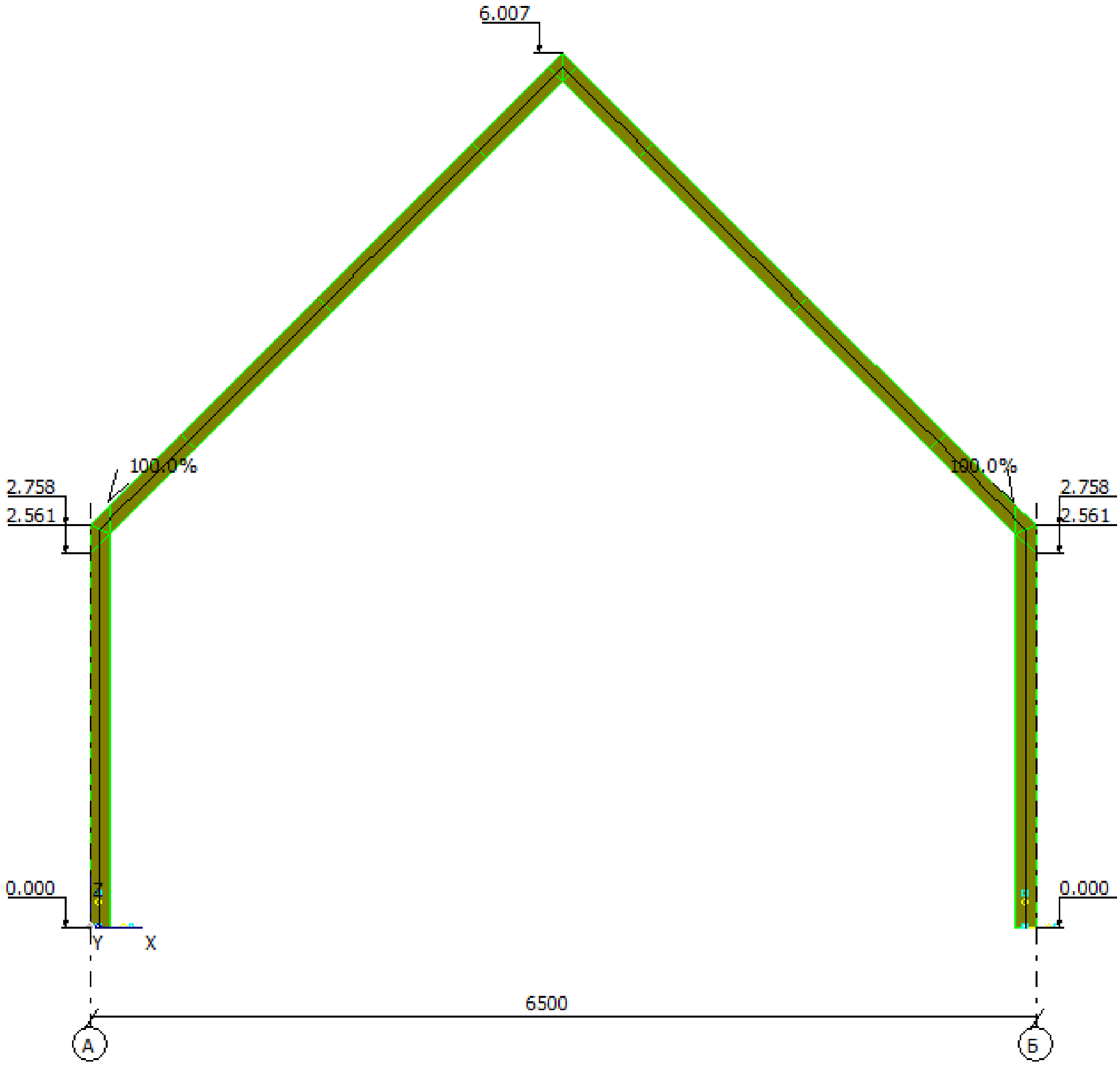

Fig. 8. FINHA-V150 building frame

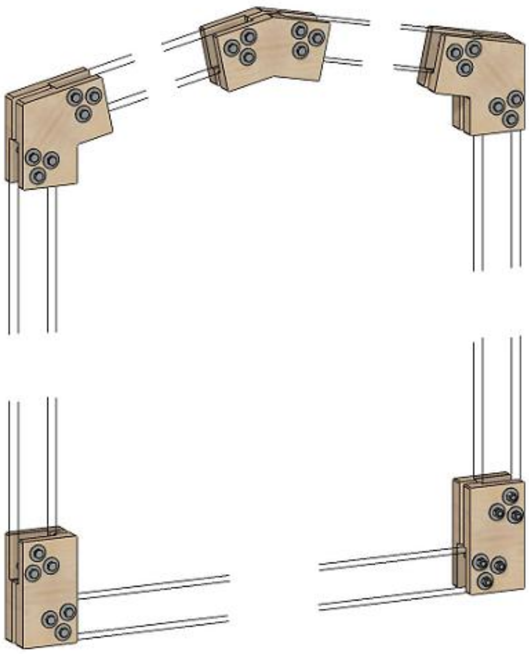

Fig. 9. Building connectors FINHA-W150

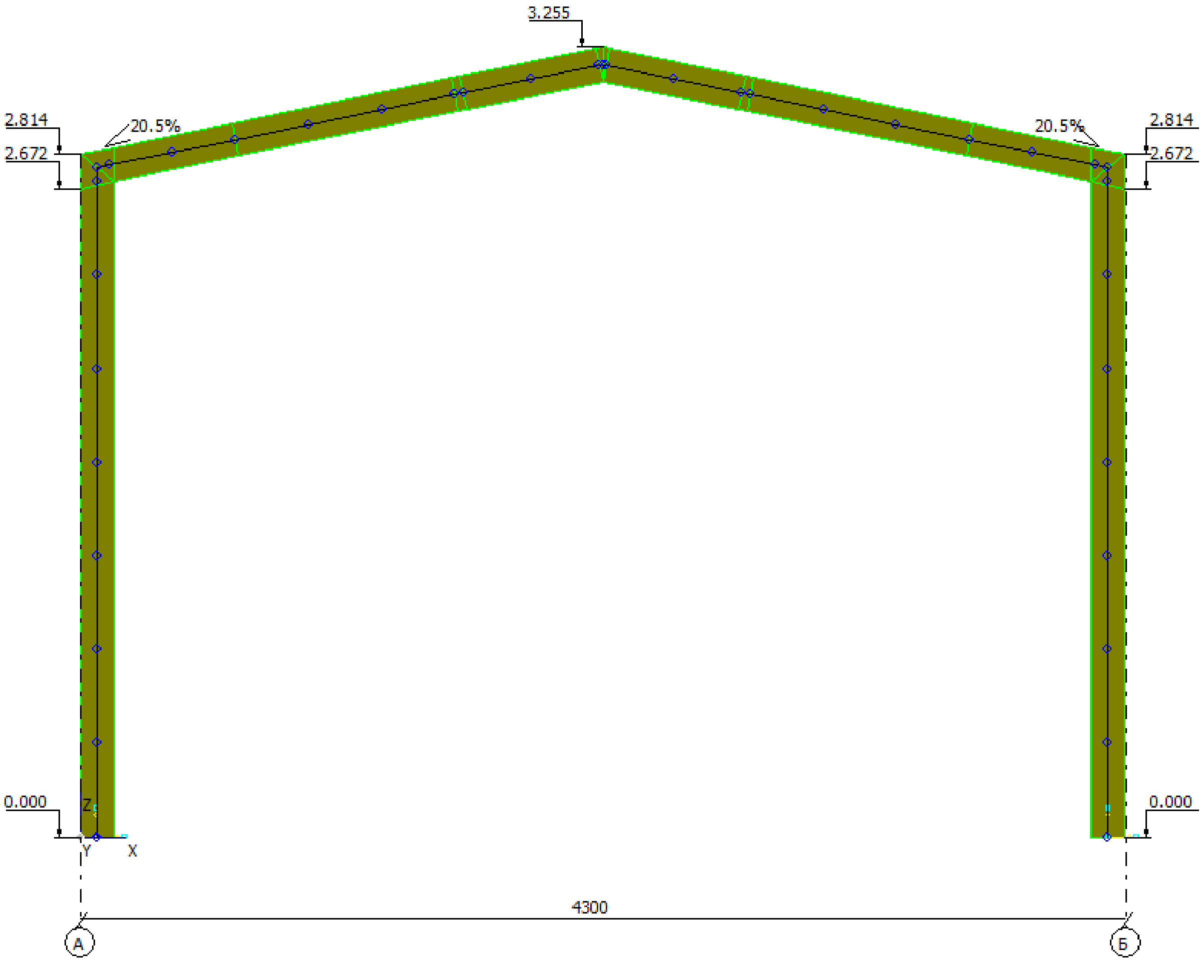

Fig. 10. FINHA-W150L building frame

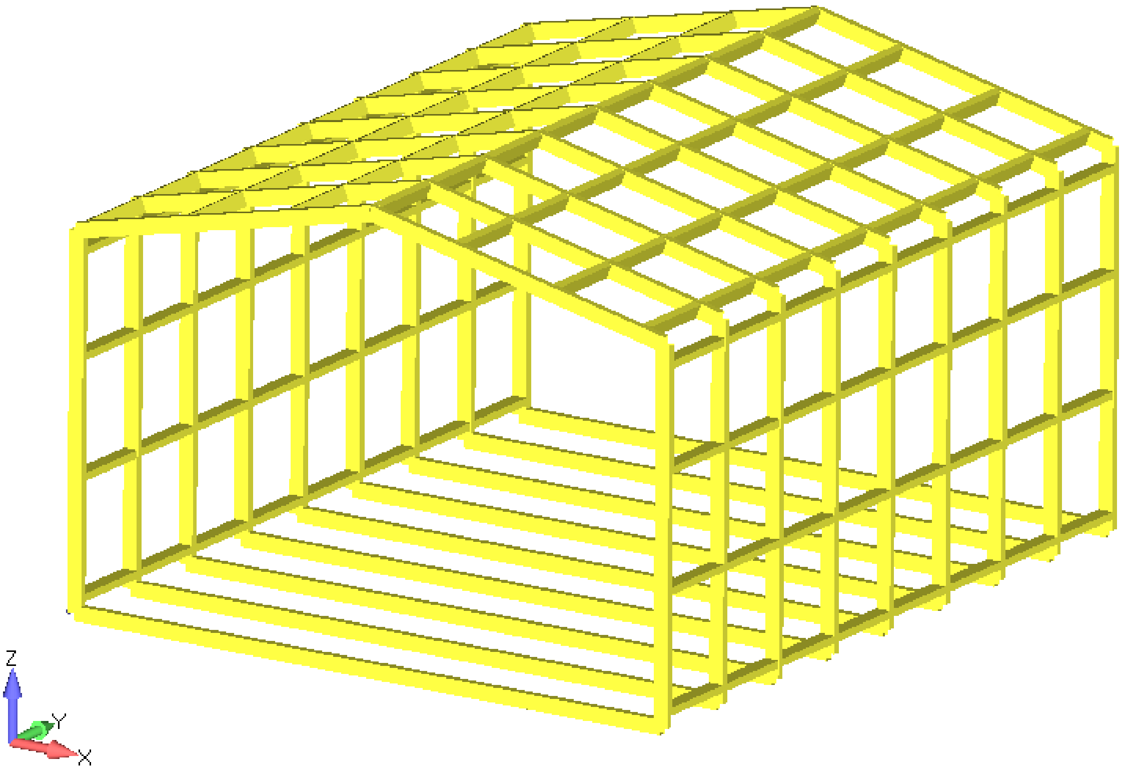

Fig. 11. General view of the FINHA-A150L gable roof building frame, 2.4 meters wide, slope is 12 deg.

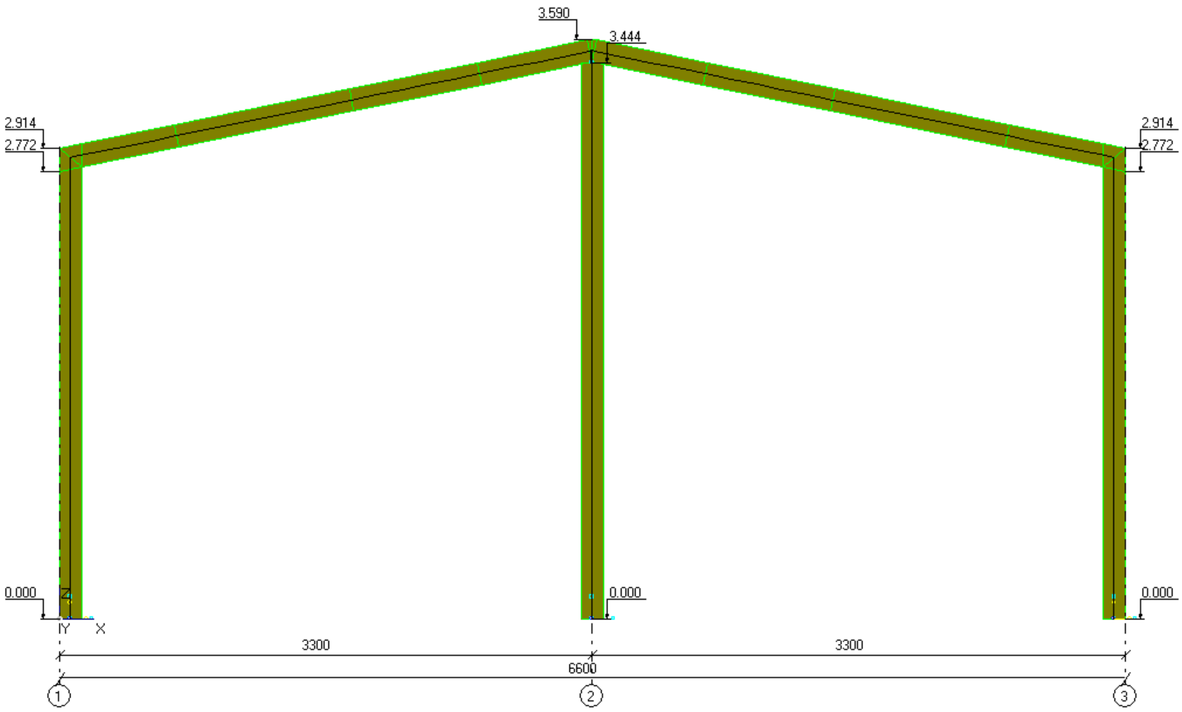

Fig. 12. FINHA-M150L building frame

1.2 Units

The following units are used in this calculation:

- Force – N;
- Length – mm;
- Stress – MPa;

1.3 Materials used and reference data

Wood, grade 1, table 3 [1] :

- $R^A_{bend} = R_{comp} =$ 24 MPa;
- $R^A_p =$ 15 MPa;

The design resistance is determined by the relation 1 [1]

$$R^p = R^A \cdot m_{дл} \cdot \Pi m_i$$

The coefficient of long-term strength $m_{дл}$ is taken from the table 4 [1]

- $m_{дл}$ = 0.66 - under the combined action of permanent and short-term loads;
- $m_{дл}$ = 0.92 - under the combined action of permanent and seismic loads.

Working conditions coefficients, p. 6.9 [1]:

- $m_b =$ 0.9 on table. 9;
- $m_t =$ 1.0;

- $m_{сл} =$ 1.0 on table. 11;
- $m_{cc} =$ 1.0 on table. 13 ;

$\Pi m_i = m_b \cdot m_t \cdot m \cdot m_{cc} =$0.9*1.0*1.0*1.0=0.9

Design value of resistance to bending and compression:

- $R^A_{bend} = R_{comp} =$24*0.66*0.9 = 14 MPa - under the combined action of permanent and short-term loads;
- $R^A_{bend} = R_{comp} =$24*0.92*0.9=20 MPa - under the combined action of permanent and seismic loads.

Design value of resistance to tension:

- $R^A_p =$15*0.66*0.9=8.9 MPa - under the combined action of permanent and short-term loads;
- $R^A_p =$15*0.92*0.9=12.4 MPa - under the combined action of permanent and seismic loads.

Design bearing strength:

- along the grain $R^A_{cr0} = R^A_{bend}$ = 14 MPa;
- cross-grain $R^A_{cr90} =$4.5 MPa.
- under 45-degree loading., r.6[1]:

  $R^A_{cr45} = R^A_{cr0} / (1 + (R^A_{cr0} / R^A_{cr90} - 1) \cdot \sin^3 45)$=8.0 MPa

Plywood:

Design value of resistance:

- R^A= 14 MPa - under the combined action of permanent and short-term loads;
- R^A= 20 MPa - under the combined action of permanent and seismic loads.

The calculation is performed for a group of static loads and a group of seismic loads, on the basis of which the design load combinations are formed.

1.4 Static loads

1. Building's own weight, permanent loading (**weight**).

   Weight loads are determined by acceleration along the vertical axis $a = g \cdot \gamma_{Gf}$,

   where

   g = 9810 mm/c^2, γ_{Gf}= 1.2 – load safety factor.

2. Floor beam load weight, temporary loading (**load**);

   The load value is taken in accordance with p. 8.2.2 and table 8.3 [2]:

$q = P_1 \cdot \gamma_f$ =0.0015*1.3 = 0.00195 MPa,

There P_1 = 0.0015 MPa – nominal value of uniformly distributed load;

γ_f = 1.3 – load safety factor.

3. Snow loads: Snow on the left (**snow left**) and Snow on the right (**snow right**), temporary loadings:

   Nominal value of uniformly snow load, p.10 [2]

   $S_0 = c_e \cdot c_t \cdot \mu \cdot S_g$

   There

   $c_e \cdot$ = 1.0 – snow drifting factor is taken in accordance with p. 10.6 [2];

   $c_t \cdot$ = 1.0 – thermal coefficient;

   μ – the conversion factor from the weight of the snow cover of the ground to the snow load on the roof is taken in accordance with p. 10.4 [2] ;

   μ=1.0 – for roof slope angle up to 30 deg;

   μ=0.5 – for roof slope angle up to 45 deg;

   For angles greater than 45 degrees, it is taken into reserve μ=0.5;

   S_g = 2.0 kN/m^2 – nominal value of snow cover weight on 1 m^2 for the snow region IV.

   Design value of snow load:

   $S = S_0 \cdot \gamma_{Sf}$,

   γ_{Sf} =1.4 – load safety factor for snow load.

   Design snow load value:

   $S = S_0 \cdot \gamma_{Sf}$,

   γ_{Sf} =1.4 – snow load safety factor

4. Wind loads, temporary loadings (**wind left** and **wind right**):

   Nominal value of wind pressure is taken in accordance with p.11.1.4 [2] for the wind region II:

   w_0 = 0.3 kN/m^2;

   γ_{Wf} =1.4 – load safety factor for wind load.

1.5 Design load combinations

The coefficients in load combinations are taken in accordance with p. 6.2, 6.3, 6.4 [2] and p. 5.1 [3]

The basic combinations

1. weight + load + snow_left + snow_right + 0.9*wind_left
2. weight + load + snow_left + snow_right + 0.9*wind_tor
3. weight + load + 0.9*snow_left + 0.9*snow_right +wind_left

1.6 Assigning loads and constrains

The static loads from weight (**weight**) are given in the form of acceleration

g = -9810*1.2=-11770 mm/c^2, (considering $\gamma_{Gf} = 1.2$) along the Z coordinate axis.

Snow and wind loads are specified as distributed loads applied to beams and studs.

The building model is pivotally fixed at the support points on the piles.

2. STRENGTH ANALYSIS

3. The frames are modeled using 140x50 mm Beam-type elements. Connectors are not modeled. Their strength, as shown in the calculation [4], is higher than that of the boards.

2.1 Frame A100, span 10 m

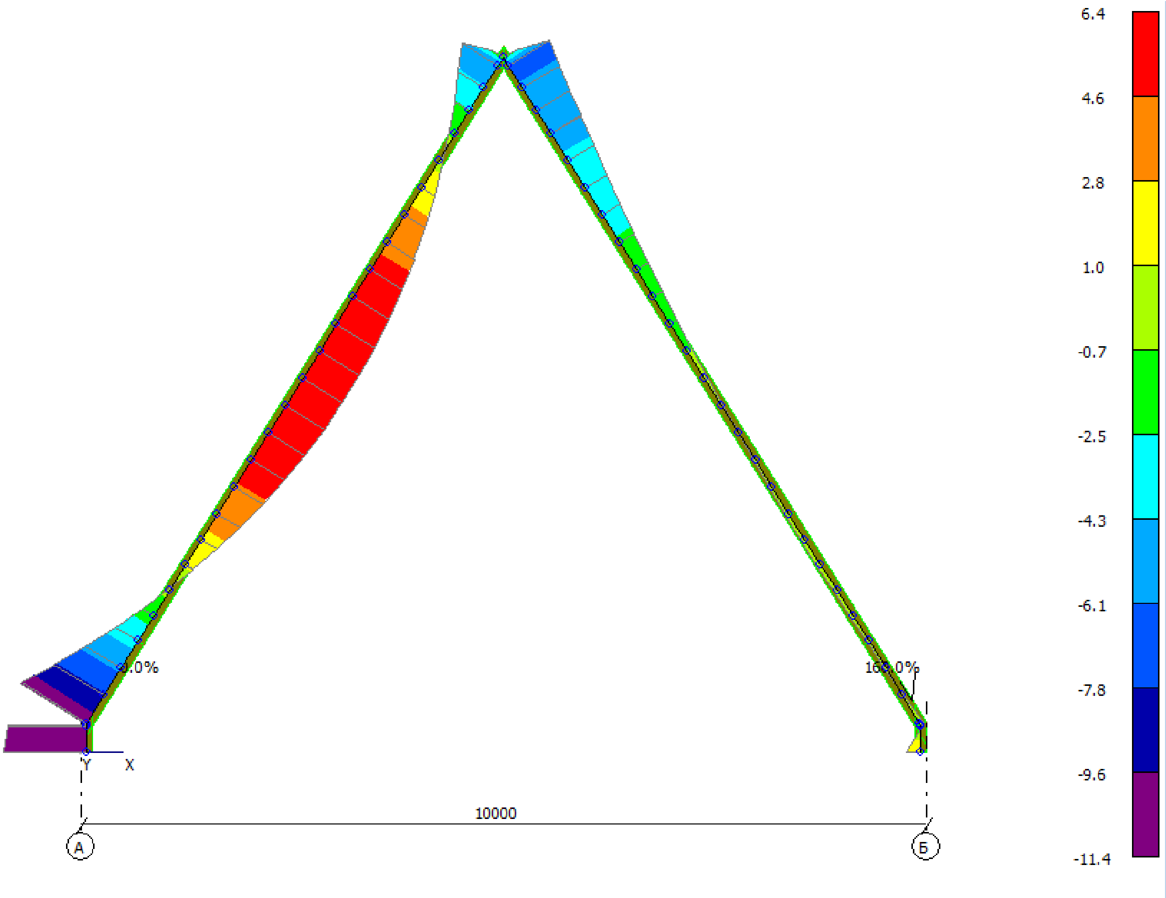

Fig. 13. Frame A150, maximum stresses in basic load combinations, MPa

Maximum bending stresses in frame elements: σmax = 11.4 MPa, fig. 13:,

- Factor of safety $\eta = R_p^A / \sigma_{\max} = 14/11.4 =$ **1.23**
- Utilization rate $f = 1/\eta$ = **0.81**

2.2 Frame P150L, span 4.1 m

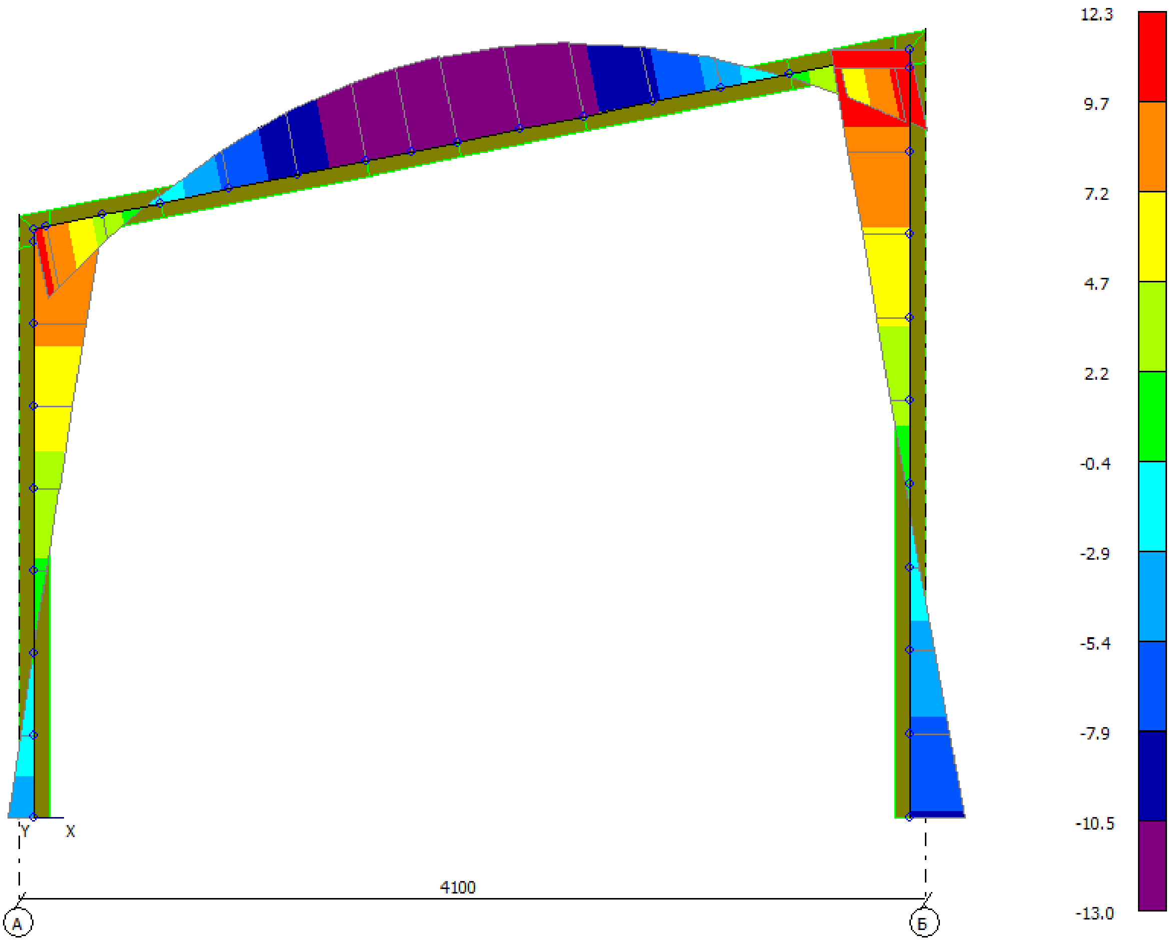

Fig. 14. Frame P150L, maximum stresses in basic load combinations, MPa

Maximum bending stresses in frame elements: σmax = 13.0 MPa, fig. 14:

- Factor of safety $\eta = R_p^A / \sigma_{\max} = 14/13 =$ **1.08**
- Utilization rate $f = 1/\eta$ = **0.93**

2.3 Frame V150, span 6.5 m

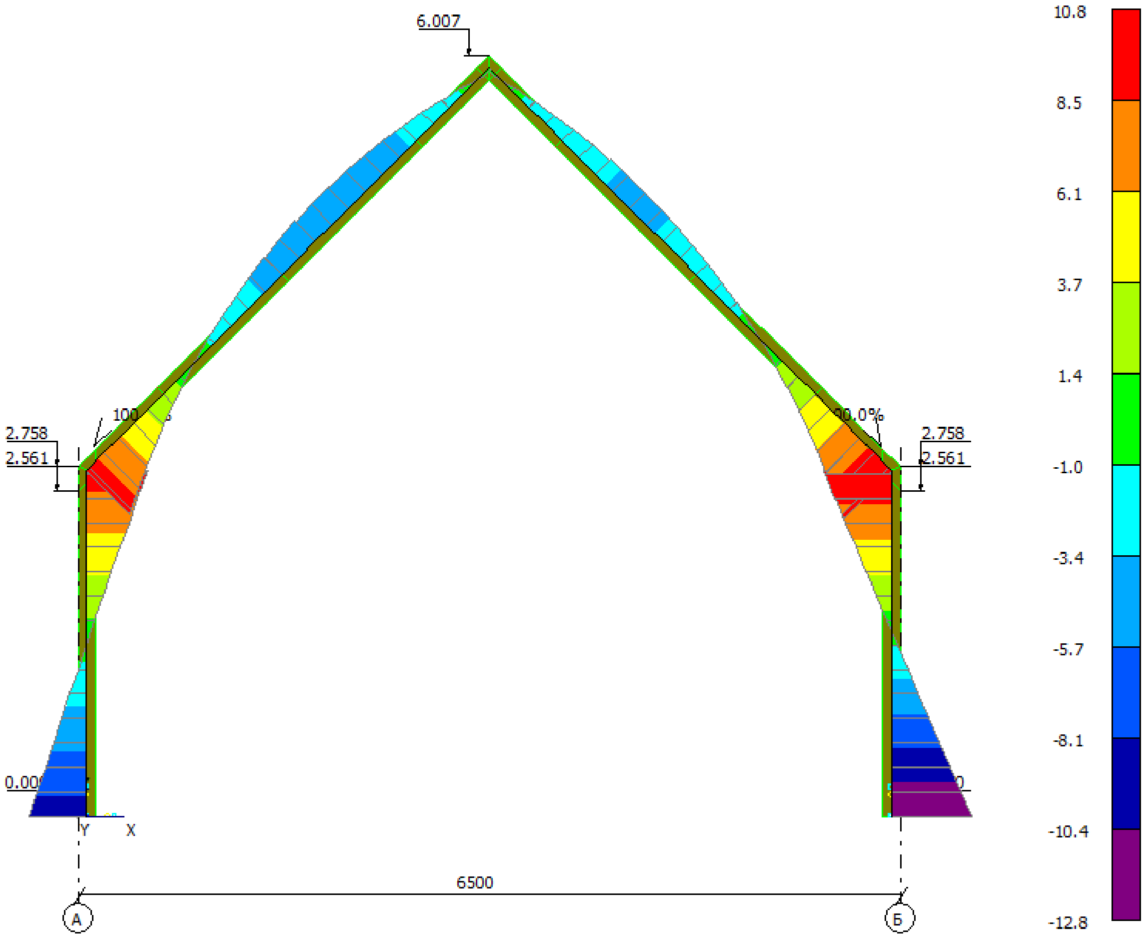

Fig. 15. Frame V150, maximum stresses in basic load combinations, MPa

Maximum bending stresses in frame elements: σmax = 12.8 MPa, fig. 15,

- Factor of safety η= R_p^A / σ_{max} =14/12.8 = **1.09**
- Utilization rate *f*=1/η = **0.91**

2.4 Frames W150, W150L, span 4.3 m

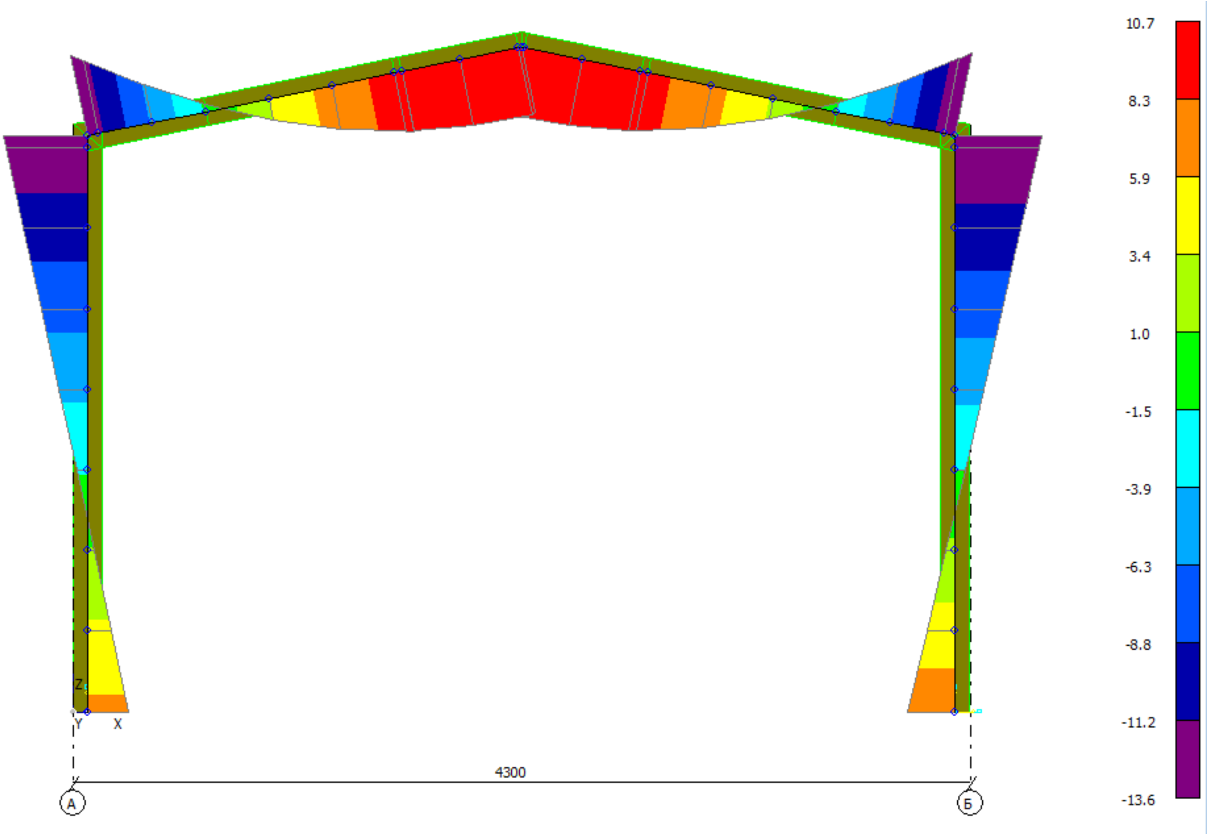

Fig. 16. Frame W150L, maximum stresses in basic load combinations, MPa

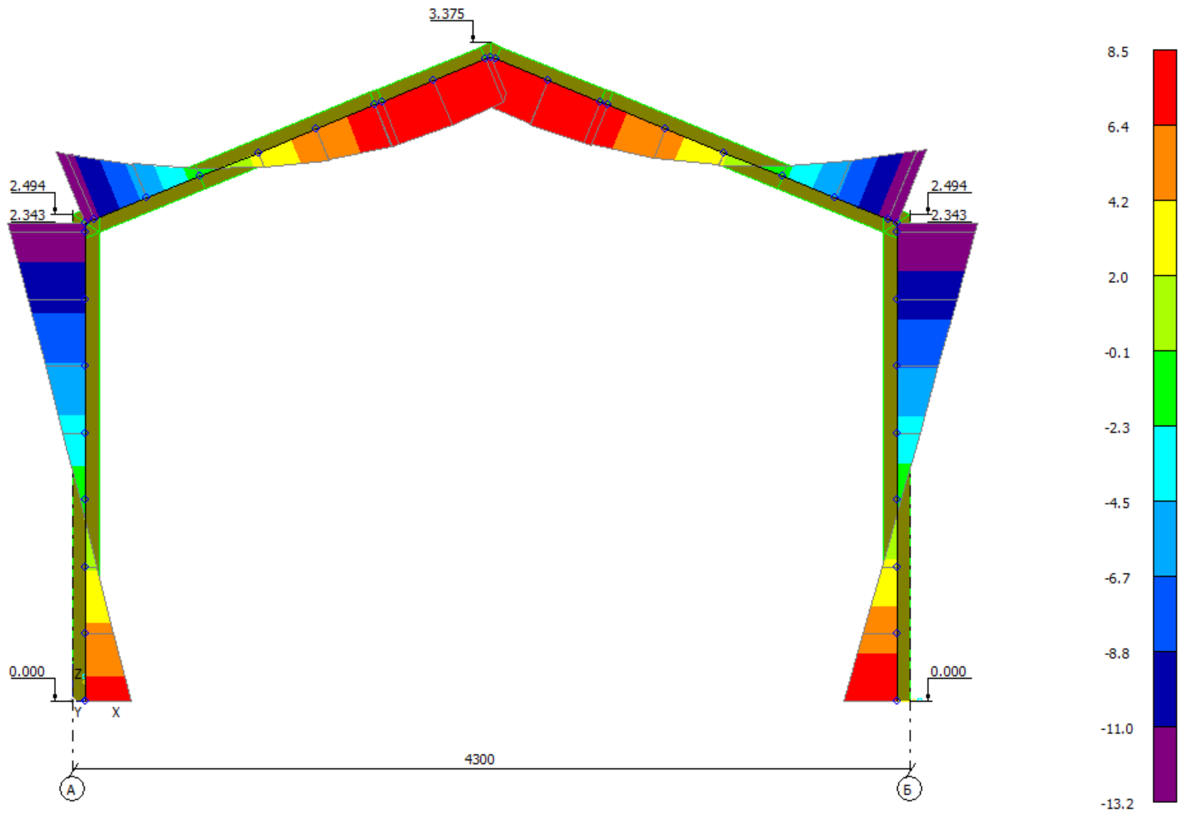

Fig. 17. Frame W150, maximum stresses in basic load combinations, MPa

Maximum bending stresses in frame elements: σmax = 13.6 MPa, fig. 16-17,

- Factor of safety $\eta = R_p^A / \sigma_{max} = 14/13.6 = \mathbf{1.03}$
- Utilization rate $f = 1/\eta$ = **0.97**

2.5 Frame M150L, span 6.6 m

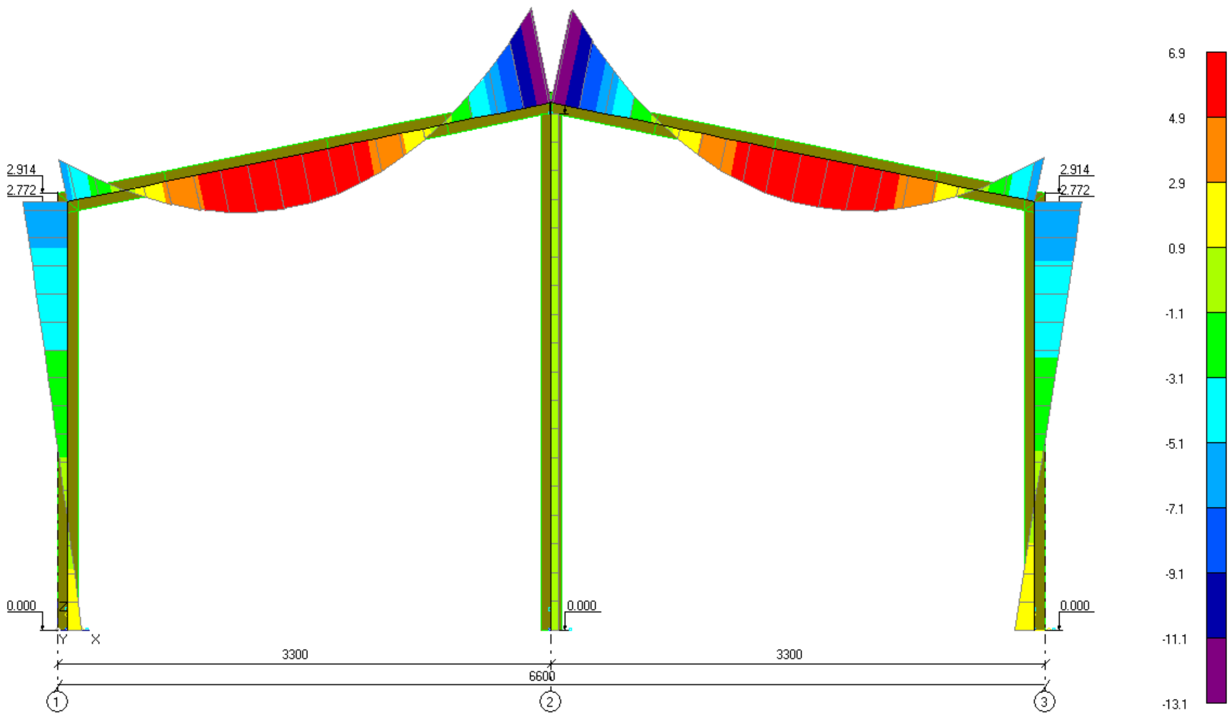

Fig. 18. Frame M150L, maximum stresses in basic load combinations, MPa

Maximum bending stresses in frame elements: σmax = 13.1 MPa, fig. 18,

- Factor of safety $\eta = R_p^A / \sigma_{max} = 14/13.1 = \mathbf{1.07}$
- Utilization rate $f = 1/\eta$ = **0.94**

CONCLUSION

Calculations for extreme operating conditions showed that the FINHA Series 100 building design meets the requirements of building code SP 64.13330.2017 "SNiP II-25-80. Wooden Structures." when building operating in the central regions of Russia.

The required building safety margin is achieved with the frame widths specified in table 1

Table 1.

Frame code	Building width, m	Stud height, m	Factor of safety
A150	10.0	-	1.23
P150L, P150LF	4.1	2.7	1.08
V150	6.5	2.7	1.09
150, W150L, W150LF	4.3	2.7	1.03
M150L	6.6	2.8	1.07

Snow loads have the greatest impact on the stress state of the frame.

LIST OF USED SOURCES

1. SP 64.13330.2017 SNIP II-25-80. Wooden Structures
2. SP 20.13330.2016 SNIP 2.01.07-85*. Loads and impacts
3. Technical report “Calculation of the supporting structure of the FINHA-2 series of buildings” 2020