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Application of Composite Materials in Building Materials

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Abstract

Composite materials play an important role in increasing the strength of building structures. Composite materials allow varying physical and mechanical characteristics due to the possibility of positioning the base made of a composite material at different angles to the trajectories of maximum stresses acting in structures made of a composite material. In construction, the composite material is placed in the building material body to increase the strength of the building materials. Since the composite material has the greatest strength in cases where the base is located along the lines of maximum stresses, it is important to determine the paths of maximum stresses in the structure under the action of operational loads. At the same time, some layers of the multilayer composite material must be angled to the maximum stress paths in order to absorb shear stresses. The resulting stress-strain state is further divided into layers to determine the stresses of individual layers of the multilayer composite material. The questions and problems of using in building structures one of the most promising modern materials - composite materials with high specific strength and not subject to corrosion are considered. Construction materials reinforced with multilayer composite materials are considered. A comparison is made of the physical and mechanical characteristics of building materials and structures using composite materials and without composite materials in building structures under operational loads.

INTRODUCTION

Modern building materials, such as foam concrete and aerated concrete, are becoming more widespread in construction due to their thermal insulation and sufficient strength characteristics. At the same time, foam concrete and aerated concrete, having compression characteristics acceptable for two-three-storey houses, have low tensile and shear characteristics. This disadvantage can be eliminated by using composite materials in building materials. Composite materials, due to their characteristics, depending on the location of the base of the composite material, are increasingly used in various fields, including in building materials. In building materials, the composite material can be enclosed in a building material body, which can significantly improve the strength characteristics of the building structure. The use of composite material in building structures is a complex task that requires a lot of theoretical and experimental research in the development and production process. Therefore, the use of a composite material, which makes it possible to significantly increase the physical and mechanical characteristics of a building material in critical directions, is an important and urgent problem. Therefore, the issues of increasing the bearing capacity of gas silicate concrete and foam concrete are topical. One of the effective ways to increase the permissible tensile stresses of gas silicate blocks is to reinforce them with composite materials.

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METHODS

To solve the problem posed, the Lagrange equation based on the Hamilton-Ostrogradsky variation principle is used .

$$\frac{\partial U}{\partial q_k} = Q_k$$

Here U is the potential energy of the system; Q - external loads q - generalized displacements, k - degrees of freedom.

Consider the stress-strain relationship equations for multilayer shells (Figure 1) in the reduced stiffness method. Matrices of elastic coefficients for an orthotropic material, the orthotropic axes of which coincide with the coordinate axes, in the plane-stressed state have the form

$$\{\sigma\} = [E]\{\varepsilon\}$$

$$[E] = \begin{Bmatrix} Q_{11} & Q_{12} & 0 \\ Q_{21} & Q_{22} & 0 \\ 0 & 0 & Q_{66} \end{Bmatrix} \qquad \{\varepsilon\}^T = \{\varepsilon_s,\ \varepsilon_\theta,\ \varepsilon_{s\theta}\}, \qquad \{\sigma\}^T = \{\sigma_s,\ \sigma_\theta,\ \sigma_{s\theta}\}$$

$$Q_{11} = E_s/(1 - v_{s\theta}v_{\theta s}), Q_{12} = v_{s\theta}E_s/(1 - v_{s\theta}v_{\theta s}), Q_{21} = v_{\theta s}E_s/(1 - v_{s\theta}v_{\theta s}),$$

$$Q_{22} = E_\theta/(1 - v_{s\theta}v_{\theta s}),$$

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When the coordinate axes are rotated through an angle θ, the matrix of elastic coefficients is transformed to the form

$$[\bar{E}] = \begin{Bmatrix} \bar{Q}_{11} & \bar{Q}_{12} & \bar{Q}_{16} \\ \bar{Q}_{21} & \bar{Q}_{22} & \bar{Q}_{26} \\ \bar{Q}_{61} & \bar{Q}_{62} & \bar{Q}_{66} \end{Bmatrix},$$

$$\bar{Q}_{11} = c^4 Q_{11} - s^4 Q_{22} + 2(Q_{12} + 2Q_{66})s^2c^2,$$
$$\bar{Q}_{12} = (Q_{11} + Q_{22} - 4Q_{66})s^2c^2 + (s^2+c^2)Q_{22},$$
$$\bar{Q}_{16} = (c^2Q_{11} - s^2Q_{12} + (Q_{12} + 2Q_{66})(s^2-c^2))sc,$$
$$\bar{Q}_{26} = (s^2Q_{11} - c^2Q_{12} - (Q_{12} + 2Q_{66})(s^2-c^2))sc,$$
$$\bar{Q}_{66} = (Q_{11} - 2Q_{12} + Q_{22})s^2c^2 + (s^2-c^2)Q_{66},$$
$$\bar{Q}_{22} = s^4Q_{11} - c^4Q_{22} + 2(Q_{12} + 2Q_{66})s^2c^2,$$
$$s = \sin\theta, c = \cos\theta$$

Finally, the matrix of elastic characteristics of an arbitrary orthotropic layer has 6 components

(6)

.For a layer located at a distance z from the median surface, the deformations are presented in the form.

$$\{\varepsilon\} = \{\varepsilon^o\} + z\{\chi^o\},$$

$\{\varepsilon^o\}$ are defomations of the middle surface, $\{\chi^o\}$ are chanes in curvature.

$$\{\sigma\} = [\bar{E}]\{\varepsilon^o\} + z[\bar{E}]\{\chi^o\}$$

$$\{N\} = \int_{-h/2}^{h/2}\{\sigma\}dz, \ \{N\}^T = (N_s, \ N_\theta, \ N_{s\theta})$$

$$\{M\} = \int_{-h/2}^{h/2}\{\sigma\}zdz, \ \{M\}^T = (M_s, \ M_\theta, \ M_{s\theta})$$

$$\begin{pmatrix} \boldsymbol{N} \\ \boldsymbol{M} \end{pmatrix} = \begin{pmatrix} A & B \\ B & D \end{pmatrix}\begin{pmatrix} \varepsilon^o \\ \chi^o \end{pmatrix}$$

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$$\left(A_{ij},\ B_{ij},\ D_{ij}\right) = \int_{-h/2}^{h/2} \overline{Q}_{ij}(1, z, z^2)\, dz\ , (i, j = 1{,}2{,}3).$$

$$A_{ij} = \sum_{k=1}^{n} \bar{Q}_{ij}(h_k - h_{k-1}),\ i, j = 1{,}2{,}6$$

$$D_{ij} = \sum_{k=1}^{n} \bar{Q}_{ij}({h^3}_k - {h^3}_{k-1}),\ i, j = 1{,}2{,}6.$$

$$B_{ij} = \sum_{k=1}^{n} \bar{Q}_{ij}({h^2}_k - {h^2}_{k-1}),\ i, j = 1{,}2{,}6$$

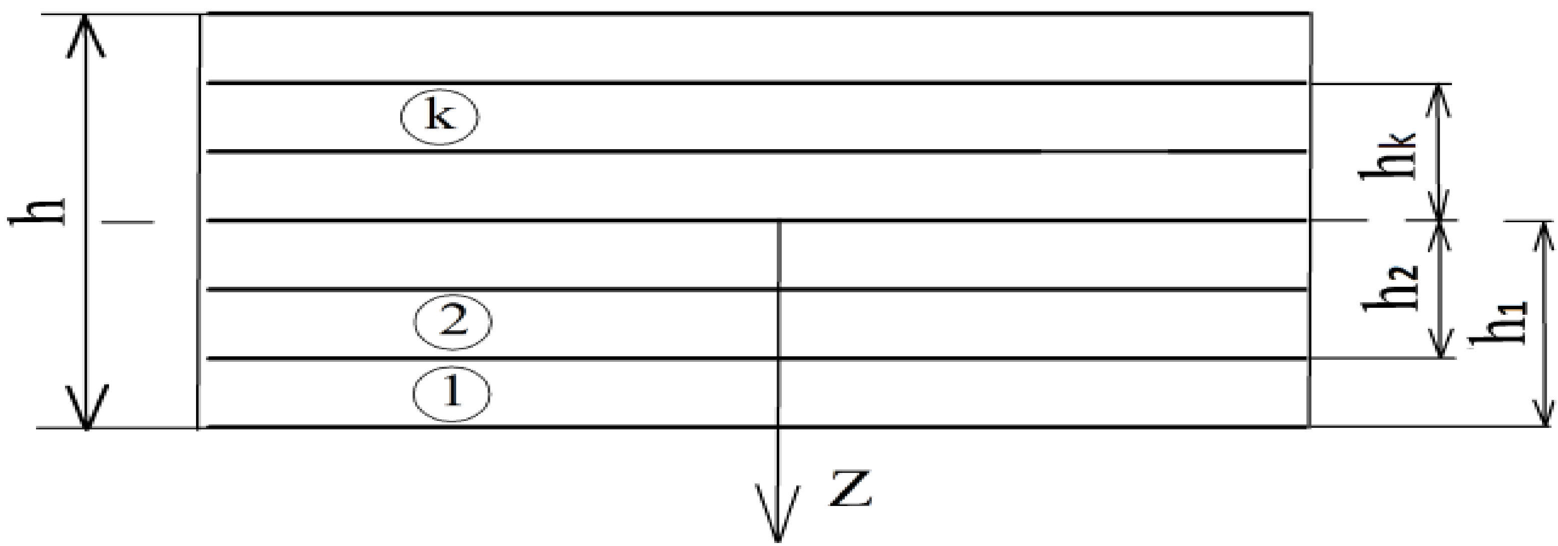


FIGURE 1. Multilayer composite material

The equations for determining the stress-strain state are obtained from the Lagrange equations. To derive the resolving equations, it is necessary to determine the potential deformation energy of the structure and the vector of external forces. Substituting the expressions for the energies and the vector of external forces into the Lagrange equation, we obtain the resolving equations in the form

$$[K]\{q\} = \{Q\},$$

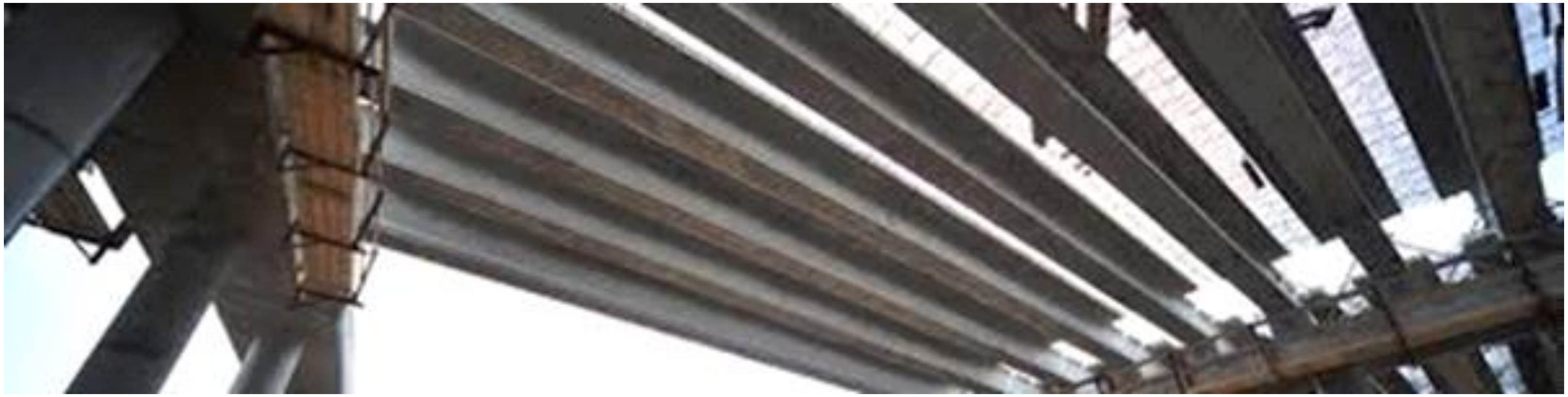
TABLE 1. Physical and mechanical characteristics of gas silicates

D500 C2.5	Design resistances for limit states of group I			Design resistances for limit states of group II		
	Axial Compression, MPa	**Tensile Strength, MPa**	**Shear Strength, MPa**	**Axial Compression, MPa**	**Tensile Strength, MPa**	**Shear Strength, MPa**
Material characteristics	1,6	0,14	0,20	2,4	0,31	0,46

TABLE 2. Physical and mechanical characteristics of composite materials

Epoxi Carbon	**Young Modulus X direction, MPa**	**Shear modulus, MPa**	**Density, kg/cm3**	**Tensile X, MPa**
Material characteristics	123340	5000	0.46	1500

Methods for strengthening building structures with composite materials



Сейчас не удается отобразить рисунок.

RESULTS

A modeling of a wall made of gas silicate blocks with dimensions of 1800 by 1000 and a thickness of 300 mm, reinforced with carbon fiber rods with a cross-sectional area of 4 by 4 mm at a length of 1800 mm (Figure 3). A tensile load of 50 MPa was applied to the ends of the wall with dimensions 1000 x 300 mm.

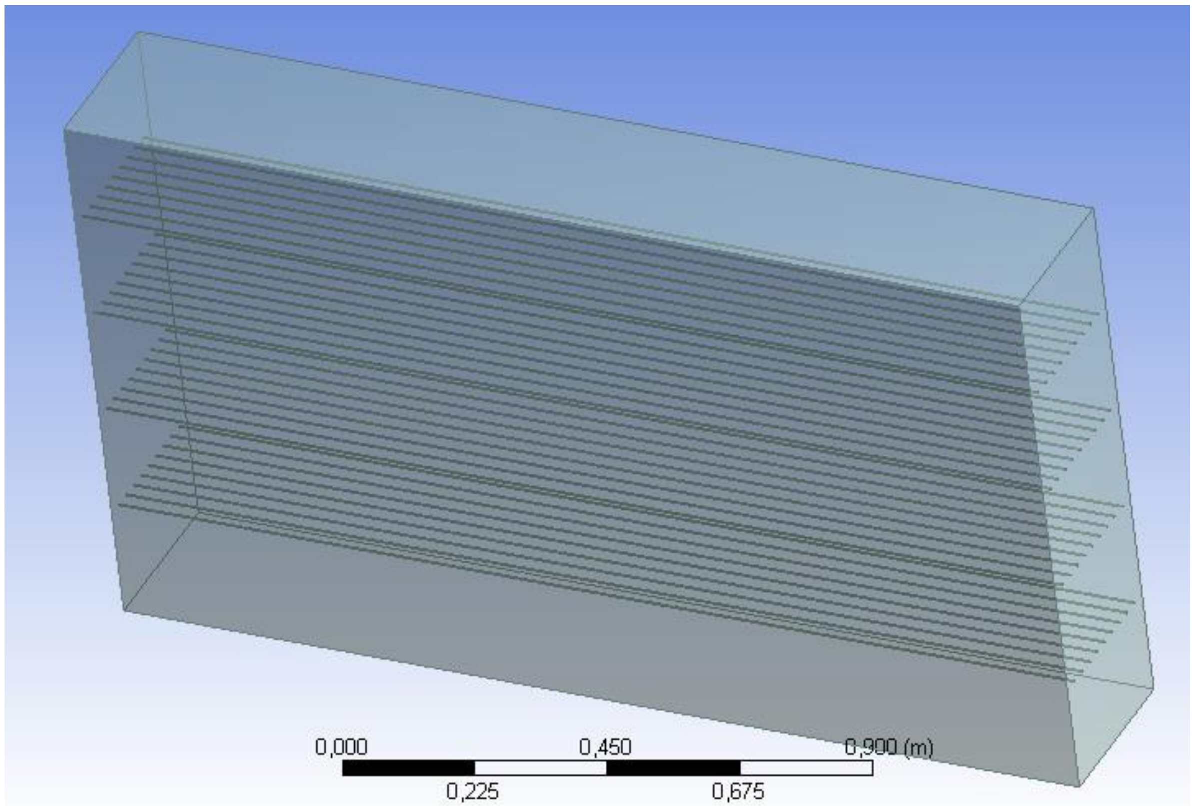


FIGURE 2. Model of a wall reinforced with composite materials

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The problem was solved by the finite element method. The total number of finite elements was 515272.

The convergence of the solution was checked by refining the finite element mesh. Calculations with 620123 numbers of finite elements differed from the initial one by no more than 2-3%.

Figures 3-7 shows the results of the calculations.

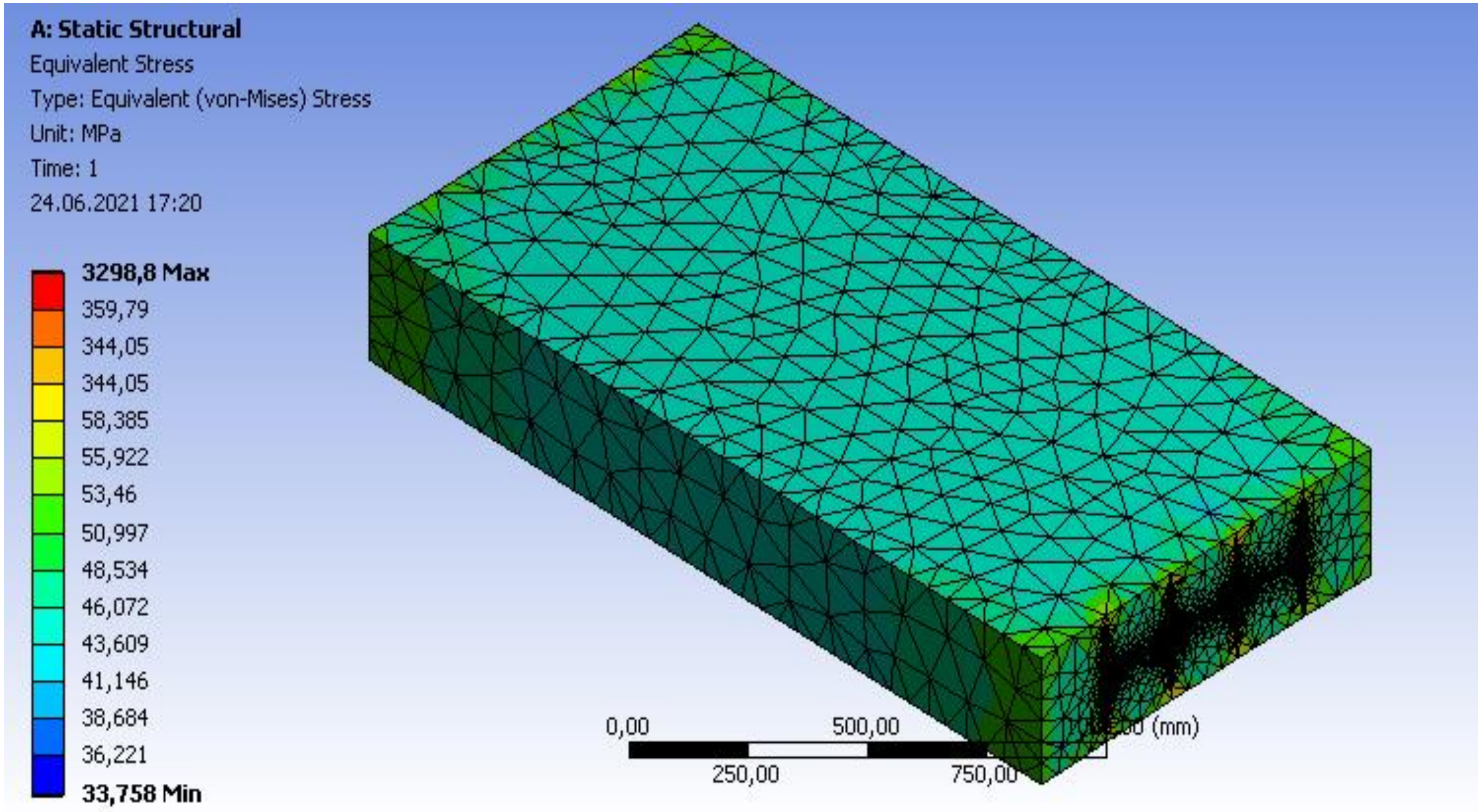

FIGURE 3. Equivalent von Mises stress

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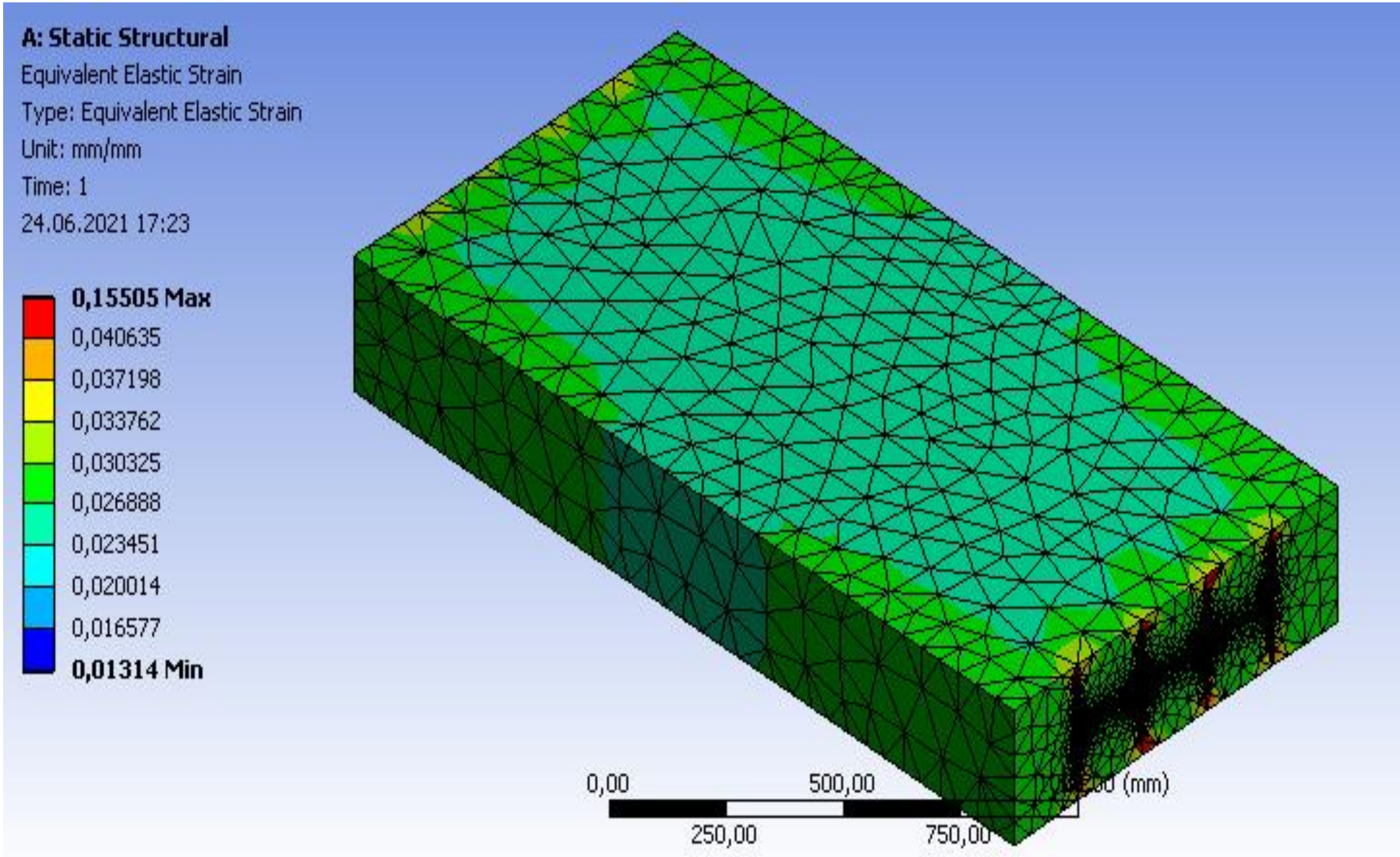

FIGURE 4. Equivalent elastic deformations

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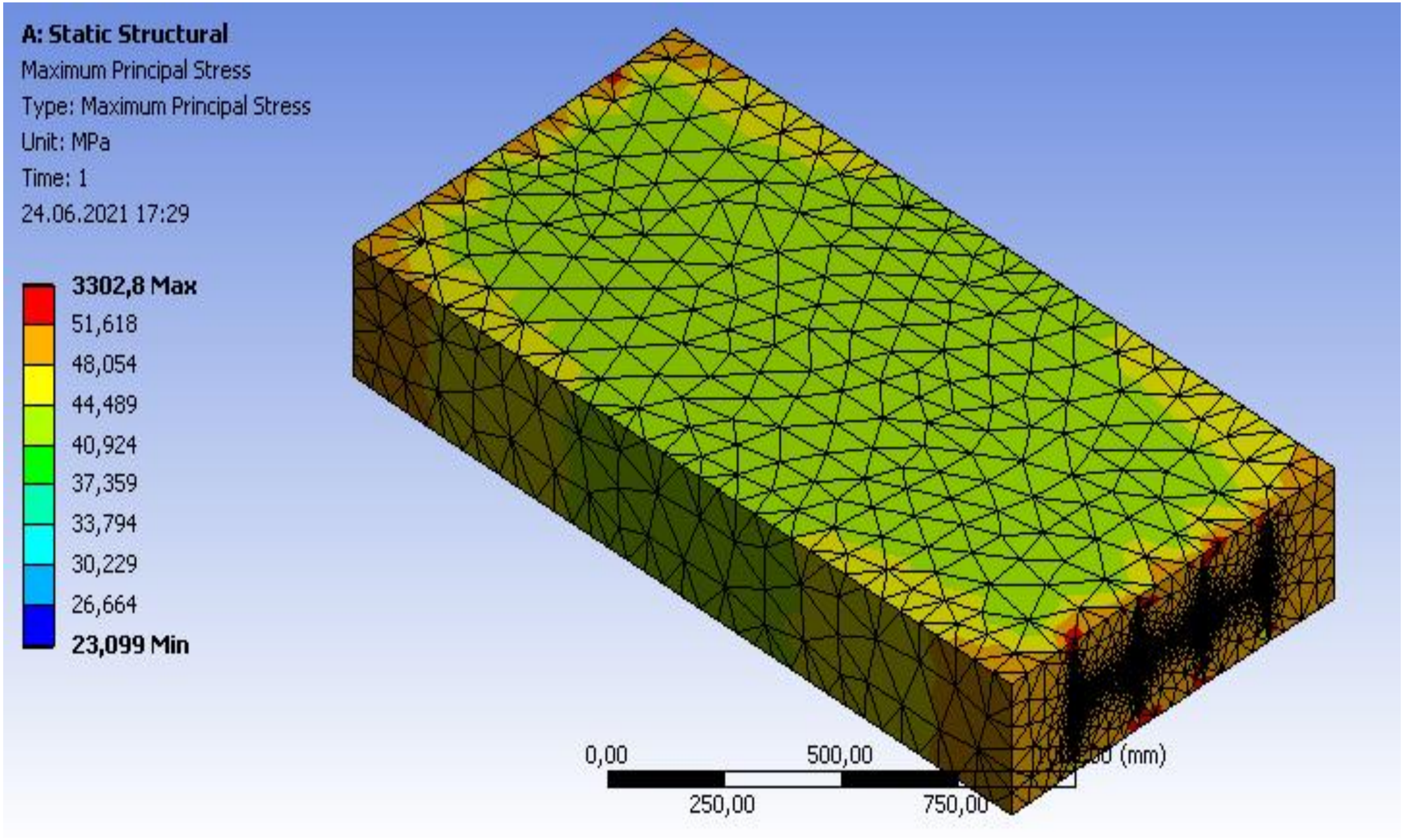

FIGURE 5. Maximum principal Stress

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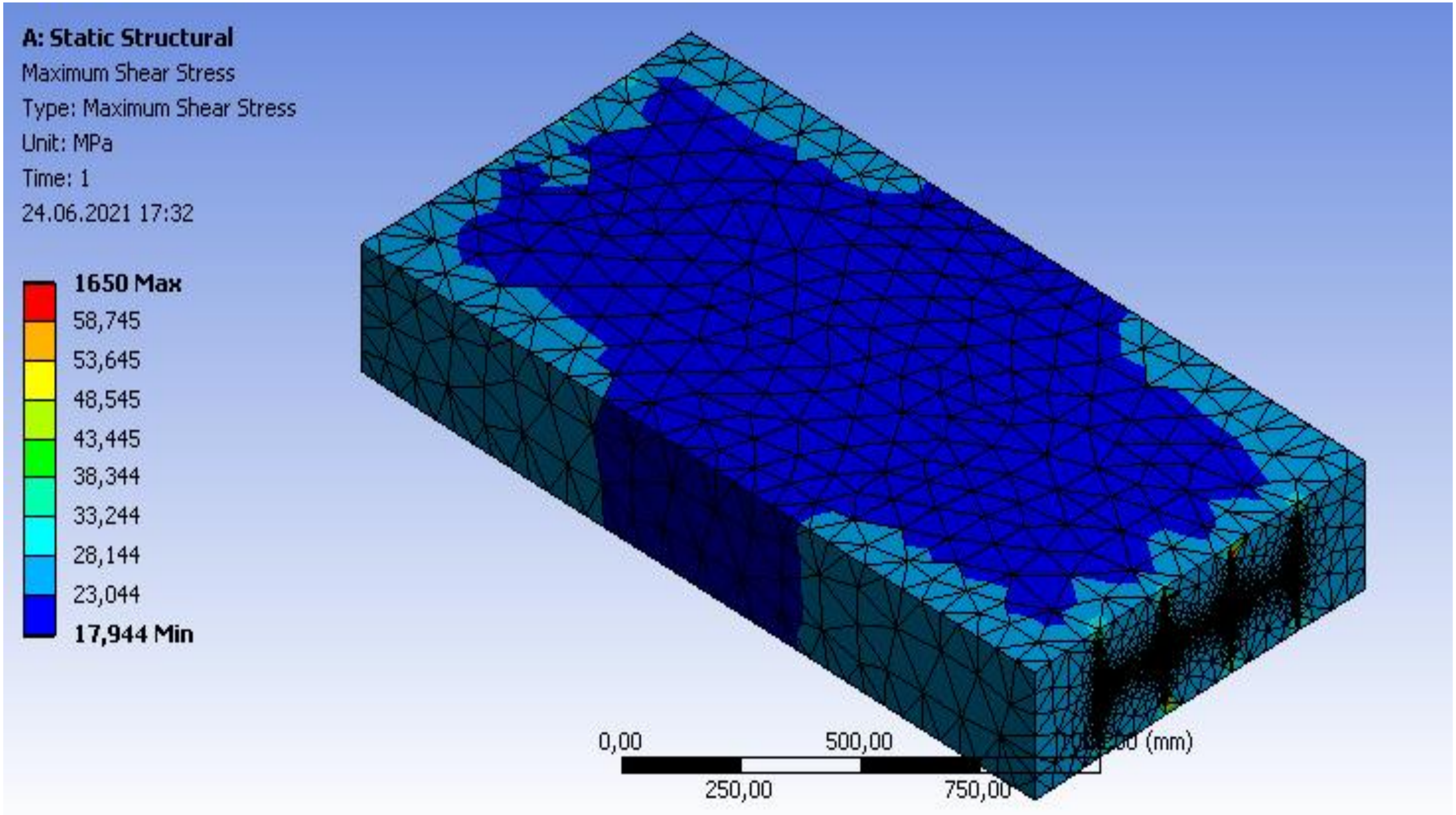

FIGURE 6. Maximum shear stresses

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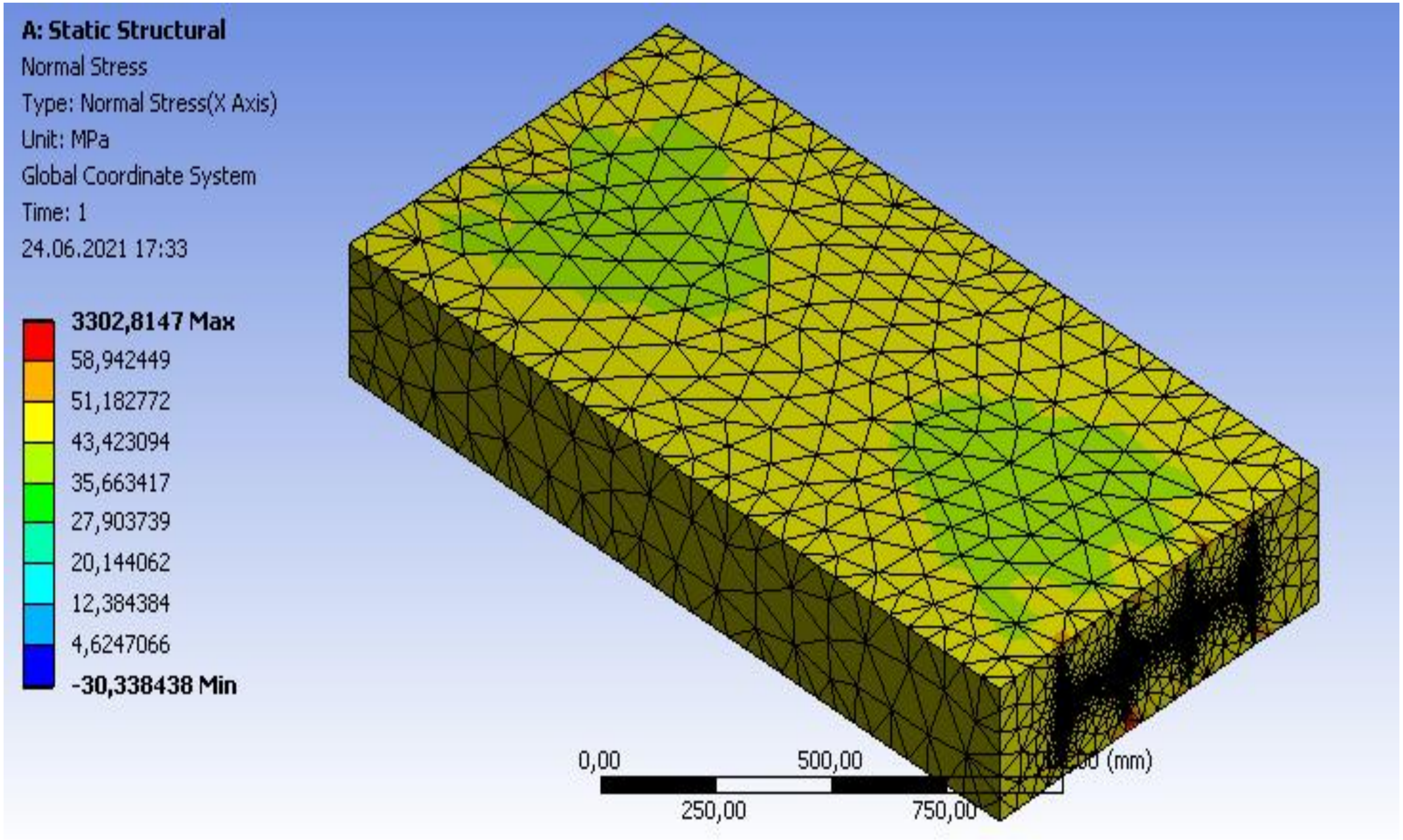

FIGURE 7. Maximum axial stresses

The analysis of the obtained results showed that the reinforcement of the wall made of gas silicate blocks with composite materials increases the strength by 25-30%.

CONCLUSION

A study of a wall made of gas silicate blocks reinforced with composite materials under the influence of temperature loads has been carried out. As a result of the study, a wall was modeled from gas silicate blocks reinforced with composite materials. The problem was solved by the finite element method. The convergence of the results obtained was checked by refining the finite element mesh. the stress-strain state of a wall made of gas silicate blocks reinforced with composite materials was obtained. The calculation of a similar wall made of gas silicate blocks was also carried out. Analysis of the results obtained and comparison with experimental data showed that the bearing capacity of a gas silicate wall when reinforced with composite materials increases by at least 25-30%.

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Thank you

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