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Research Article

INTERLAYER SHIFTS OF TWO-LAYER COMBINED PLATES TAKING INTO ACCOUNT TEMPERATURE LOADS

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ABSTRACT

This paper presents the results of research taking into account the stresses and strains of two-layer plates, which differ in terms of physical and mechanical properties, the shear deformations of the layers under the influence of temperature and the transverse displacement and inclination of adhesive joints. At the same time, interlayer displacements and other mechanical characteristics are taken into account in such a way as to allow a sufficiently accurate assessment of the strength and superiority of engineering problems for these engineering problems.

KEYWORDS

Stress-strain state, interlayer shifts, strength, transverse shear, adhesive layer, displacement, shear function, shear stresses, deflection, shear modulus, temperature effect.

INTRODUCTION

The paper presents the results of a study of the stress-strain state (SSS) of two-layer combined slabs, taking into account temperature loads. Interlayer shifts and other mechanical characteristics are taken into account, which makes it possible to estimate strength and stress-strain states with sufficiently high accuracy for engineering problems. Adhesive joints between layers serve to ensure the solidity of structures and significantly affect the redistribution of forces between layers [1-3].

When calculating the strength and stability of combined structures, taking into account the influence of the adhesive layer is especially important in cases where the structure is subject to temperature effects or when there is a risk of loss of strength and stability of two-layer boards.

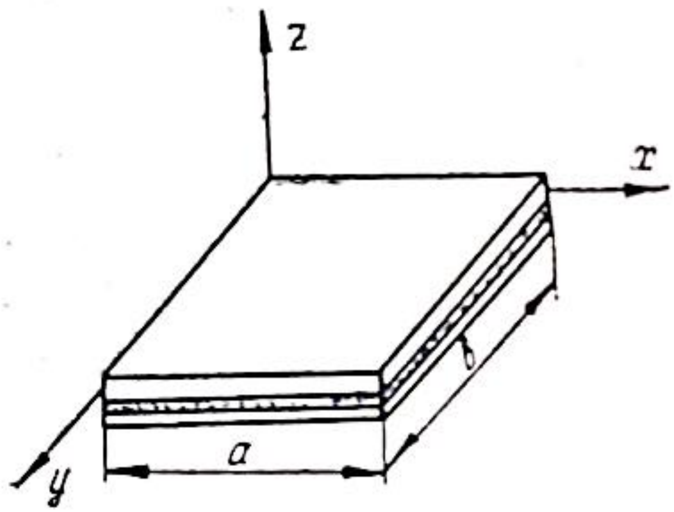

Fig 1. Two-layer combined plate.

Let us consider the study of the stress-strain state of the SSS of a two-layer slab, taking into account the transverse shear of the composite layers and the compliance of the adhesive joint (4.5).

Problems of deformability and strength of laminated two-layer slabs, taking into account interlayer shifts, built based on metal and fibreglass. [4-7] The paper considers a combined slab whose layers are interconnected by pliable thin adhesive seams under the influence of temperature and external static loads. The thermal effect has a significant effect on the behaviour of the combined two-layer material. When combined structures are heated, the stresses in the bonding and fibreglass layers change significantly. Temperature strongly influences all mechanical properties of combined

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laminated boards. In this paper, the problem of thermoelasticity of two-layer plates is solved using the refined theory of S.A. Ambartsumyan (1). It is assumed that the second fibreglass reinforcing layer has a significantly smaller thickness than the first [8-11].

The construction of the refined theory in this paper is based on energy considerations. Analysis of the effect of temperature exposure in layers and between layers was performed for a combined slab consisting of metal and fibreglass (reinforcing) layers. The two-layer slab under consideration is freely supported along the entire contour and carries a uniformly distributed load of 0 [12-16]. It is assumed that the heat flow acts in the direction of the load [15-18]. From the solution of the heat conduction problem, the following temperature distribution in the layers was obtained:

In the first layer $T_1 = T^0{}_1 + \theta_1 \gamma$

In the second layer $T_2 = T^0{}_2 + \theta_2 \gamma$ (1)

Wherein $-\frac{h}{2} \leq \gamma \leq +\frac{h}{2}$; $-\frac{\delta_n}{2} \leq \gamma_1 \leq +\frac{\delta_n}{2}$;

where θ_1, θ_2 - temperature gradients in layers;

$T^0{}_1, T^0{}_2$ - mid-plane temperatures;

Taking as usual for complete deformations:

$\varepsilon_{com}=\varepsilon_{elas} + \varepsilon_{т}$ (2)

Где ε_{elas} - elastic deformation of the system

$\varepsilon_{т}$- deformation from temperature influences

The physical law for the layers will have the form:

For the first layer

$$_x^{(I)} = C_{II}\left(\varepsilon_x^I + \mu \cdot \varepsilon_y^I\right) - C_I.T_I$$

$(x \to y, C_{11} \to C_{22}, C_1 \to C_2, \mu_{12}^I \to \mu_{21}^I)$; (3)

For the second layer

$$_x^{(II)} = B_{II}\left(\varepsilon_x^{II} + \mu_{21}^{II} \cdot \varepsilon_y^{II}\right) - D_I.T_2$$

$(x \to y, B_{11} \to B_{22}, D_1 \to D_2, \mu_{12}^{II} \to \mu_{21})$; (4)

Here

$$C_{II} = \frac{E_1^I}{1-\mu_{12}^I \cdot \mu_{21}^I}; C_{22} = \frac{E_{21}^I}{1-\mu_{12}^{II} \cdot \mu_{21}^{II}};$$

$$B_{II} = \frac{E_1^{II}}{1-\mu_{12}^{II} \cdot \mu_{21}^{II}}; B_{22} = \frac{E_2^{II}}{1-\mu_{12}^{II} \cdot \mu_{21}^{II}}; (5)$$

Where E_1^i, E_2^i - modulus of elasticity of layers (i=1,2);

$\mu_{12}^i \cdot \mu_{21}^i$- Poisson's ratio of layers (i=1,2);

$C_I = C_{II}(\alpha_{Ix} + \mu_{I2} \cdot \alpha_{Iy})$;

$C_2 = C_{22}(\alpha_{Iy} + \mu_{21}^I \cdot \alpha_{Ix})$;

$$D_I = B_{II}\left(\alpha_{2x}+\mu_{21} \cdot \alpha_{2y}\right);$$

$D_2 = B_{22}\left(\alpha_{2y}+\mu_{21}^{II} \cdot \alpha_{2x}\right)$; (6)

Where $\alpha_{1x}, \alpha_{1y}, \alpha_{2x,}\alpha_{2y}$- к coefficients of thermal expansion of the first and second layers.

The plate deformation equations are obtained using the variational principle, and the total

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energy of the system is taken as the functional. The functionality has the form:

$$И_{(Z)} = \frac{1}{2}\iint$$

With the help of Euler's variational equation, a system of fourth-order partial differential equations concerning unknowns is obtained. As an example, we take a fibreglass layer with a metal reinforcing layer.

When determining the stress-strain state of a two-layer slab, the shear and thickness of the glueing joint were varied, and the effect of changing the thicknesses of the bearing layers was studied.

RESULTS AND CONCLUSION

As an example, we consider a fibreglass layer with a metal reinforcing layer, a calculation is made of a slab hinged along the contour under the action of a uniformly distributed load, and the temperature load is also established.

It is assumed that the outer metal reinforcing layer is much thinner than the fibreglass one (Fig. 1), the calculation was made with the following parameters:

a=b=1,2, =1,5 cm, =0,2 cm

$$E_{1p}^{(1)} = 3{,}05 \cdot 10^4\ MPa,$$

$$E_{2p}^{(2)} = 1{,}88 \cdot 10^4\ MPa\ , \mathrm{E}_1^{(2)} = E_2^{(2)} = 2{,}1\ \cdot 10^5\ MPa,$$

$$\mu_{12}^{(1)} = \mu_{21}^{(1)} \cdot 0{,}18,\ \mu_{12}^{(2)} = 026, G_{12}^{(1)} = 049 \cdot 10^4\ \ \mathrm{MPa}, G_{13}^{(1)} = 0{,}31\ \cdot 10^5\ \mathrm{MPa},$$

$$G_{13}^{(1)} = 0{,}35\ \cdot 10^4\ MPa, G_{12}^{(2)} = G_{13}^{(2)} = G_{23}^{(2)} = 0{,}787 \cdot 10^5 MPa.$$

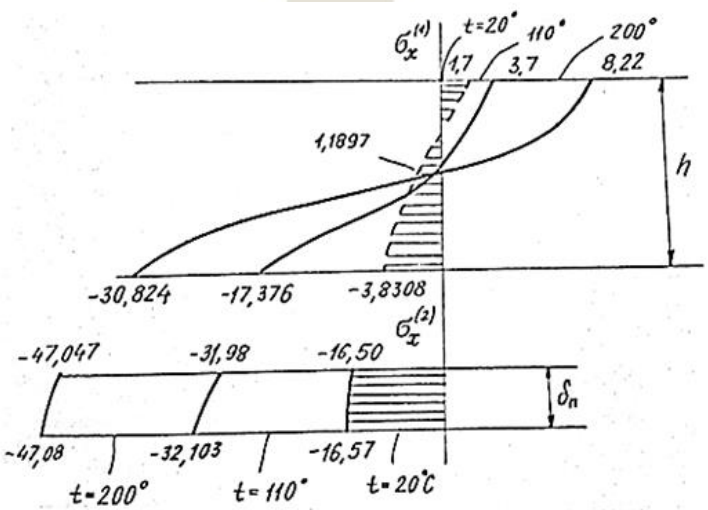

Figure 2. Changes in the stress-strain state (SSS) with a varying shear modulus of the weld.

The calculation results showed (see Fig. 2) that an increase in G_шik MPA to 5.0 MPa leads to a decrease in stresses in the fibreglass layer by 4.45%, while the stresses in the metal layer increase by 10. Changing the thickness of the adhesive layer by a factor of two (from h_ш= 〖10〗^(-2) до 0,5 〖·10〗^(-2) см)) cm to 0.5 10 cm) changes the maximum stresses in fibreglass by 4,1%.

The calculation results under the action of a temperature difference (T^(н)= 〖20 〗^0 C,T^(в)= 〖200 〗^0 C)) across the plate thickness are shown in Figure 3. When the temperature rises from 110°C to 200 °C, the maximum stress in the first layer of the composite plate changes by 50%, respectively, in the second layer it changes by 32%. The analysis showed that an increase in the thickness of the adhesive layer made of epoxy adhesive KI47 (5MPA) by 10 times (from 10 to 10 m) increases the deflection of the plate by 21% (see Fig. 2.11,) At a large value (about 5.10 MPa) The thickness of the seam has little effect on deflections (less than 1%). Regularity has been established, the greater the thickness of the bearing fibreglass layer, the less the effect of the joint shear modulus on stresses and deformability of two-layer combined slabs. The deflection of fibreglass slabs with external metal reinforcement according to the theory under consideration, taking into account the interlaminar shift at 1.5, is 64.64% less than the deflection of the slab.

The results of the calculation show that for two-layer orthotropic combined glued boards with low shear stiffness, it is necessary to take into account transverse shears and compliance of the adhesive joint. The influence of the adhesive layer turns out to be significantly higher at its low shear characteristics.

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