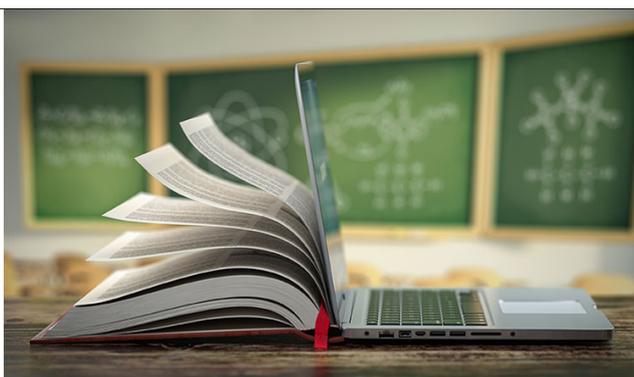


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# Multilayer facade panel structure analysis

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**Abstract.** At present, the problem of energy saving is urgent in the world community. The construction and operation of buildings accounts for over 40% of all materials and energy. The problem of energy saving is an integral part of building design. The world experience shows that one of the most effective ways to reduce specific energy consumption in buildings is additional thermal insulation of enclosing structures. The research of different types of modern facade structures of buildings has led to the development of a new type of enclosing structure - a multilayer facade panel (MFP). This article presents the description of MFP construction and the results of the finite element analysis (FEA) with ANSYS solver.

## 1. Introduction

The problem of energy saving is urgent in the developed countries. When solving the problem, the focus is on reducing specific energy consumption and increasing the use of renewable energy sources [1,2]. The world experience shows that one of the most effective ways to reduce specific energy consumption in buildings is additional thermal insulation of enclosing structures. The operation of existing modern design solutions for building facades shows a number of disadvantages:

- increased heat consumption for heating,
- design defects of facade systems leading to the immediate destruction of thermal insulation,
- high resource consumption during installation, and many others [3-7].

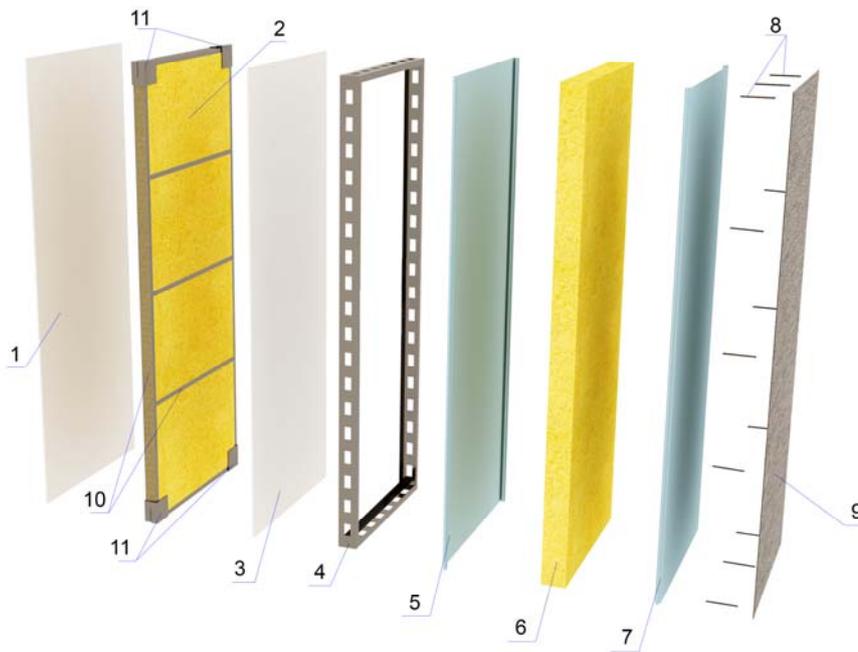
As a result of the research of modern facade solutions, a new type of enclosing structure was created - a multilayer facade panel (MFP). The prototype for the MFP was one of the trends of European architecture - the climatic façade or “double-skin” façade. The famous architect Le Corbusier is considered to be the founder of the idea of a climatic facade. The innovative idea of a "neutralizing wall" proposed by the architect at the beginning of the 20th century was to create a two-layer facade with an air gap, in which pipes for heating and cooling the air are installed [8,9]. Currently, the construction of a double glazed façade is especially common in high-rise construction. Climatic facades differ in many respects: the placement of the surfaces of the double facade, the presence of ventilation holes, the size of the gap, and others. The space between the layers serves not only as a channel for air circulation; here are located electric drives for internal and external transoms, sun protection devices, gangways for maintenance, etc [10-20].



**2. The description of MFP structure**

The MFP design (figure 1) consists of an internal (2) and external (6) heat-insulating layers, between which there is a frame made of perforated channels (4).

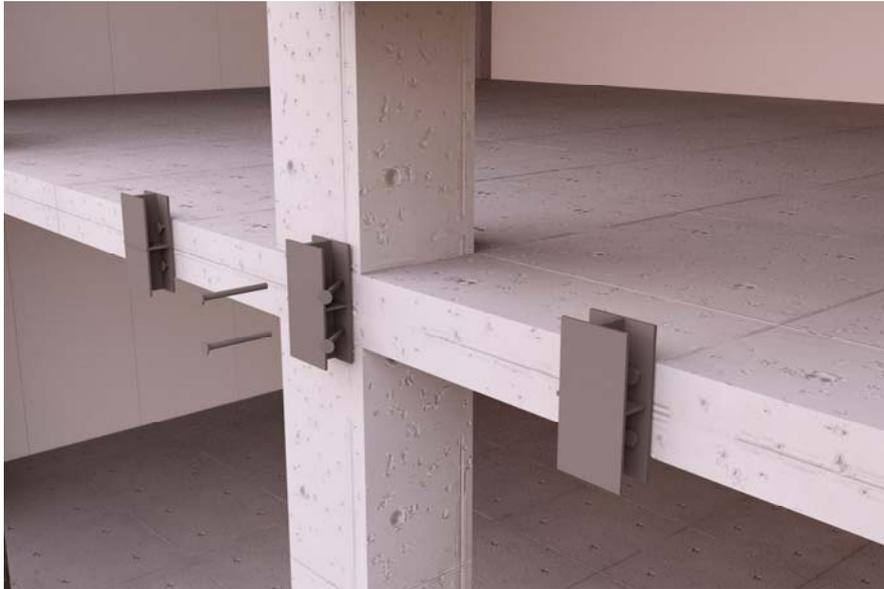
The inner layer of the panel consists of a frame made of thermoprofiles (10), faced with cement moisture-resistant slabs (3) on both sides. Between the cement slabs (1,3) (AQUAPANEL "KNAUF" or similar), thermal insulation (2) is laid on the thermal profiles (10). The cement slabs are attached to the frame (10) with self-tapping screws. The inner surface of cement slabs (1, 3) and thermal insulation (2) are bonded with an adhesive.



**Figure 1.** MFP design with numeration of layers.

Cement slabs (1,3) made of a core based on Portland cement and a light mineral aggregate, the surfaces of which are reinforced with fiberglass, protect the thermal insulation. Absolute moisture resistance, durability, incombustibility allow to preserve mineral wool throughout the entire declared service life. Fasteners (11) are installed at the four angles of the inner layer of the panel. The fastening element is a box-shaped angle with a groove into which an I-beam flange is inserted, which forms a supporting element. The fastener connects all the layers of inner part of the panel to each other and connects to the frame made of thermal profiles using self-tapping screws. The inner layer is connected to the supporting frame made of perforated channels (4) by welding: the fastening element is welded to the channels along the inner and outer edges. The frame (4) is made of channels with perforations in the horizontal and vertical directions for unimpeded airflow.

The outer layer of the panel is a three-layer prefabricated sandwich panel formed by a layer of thermal insulation (6), faced with aluminum sheets (5,7) on both sides. The connection of the outer layers of the panels is performed in the horizontal direction using the Z-lock; in the vertical direction a special strip is installed. The outer layer of the panel is attached to the supporting frame with self-tapping screws (8). A flexible solar panel (9) can be attached to the outside of the panel. The supporting element is an I-beam with ribs, fixed at the side surface of the reinforced concrete slab with anchors (figure 2).



**Figure 2.** The supporting element.

The frame made of perforated profiles for unimpeded airflow, forms an air gap along the entire façade of the building. The impermeability of the facade structure allows the use of heated air in the gap to reduce the consumption of thermal energy for heating and ventilation.

**3. Finite element analysis of strength of MFP in the software package ANSYS**

The design of the MPP for the limit states is carried out taking into account the unfavorable combinations of loads. The combinations are established from the analysis of real options for the simultaneous action of various loads for the considered stage of the panel operation.

$$C_m = P_d + (\psi_{t1}P_{t1} + \psi_{t2}P_{t2} + ..) + (\psi_{r1}P_{r1} + \psi_{r2}P_{r2} + ..) \tag{1}$$

Permanent loads  $P_d$  include the weight of the panel. Long-term loads  $P_l$  include effects caused by a change in the moisture regime of the outer layer of the thermal insulation of a sandwich panel. Short-term  $P_t$  loads include human and climatic loads.

For hinged facade systems, it is necessary to take into account the peak positive and negative effects of wind load, the normative values of which are determined by the formula:

$$\omega_{+(-)} = \omega_0 \kappa(z_e) [1 + \zeta(z_e)] c_{p,+(-)} v_{+(-)} \tag{2}$$

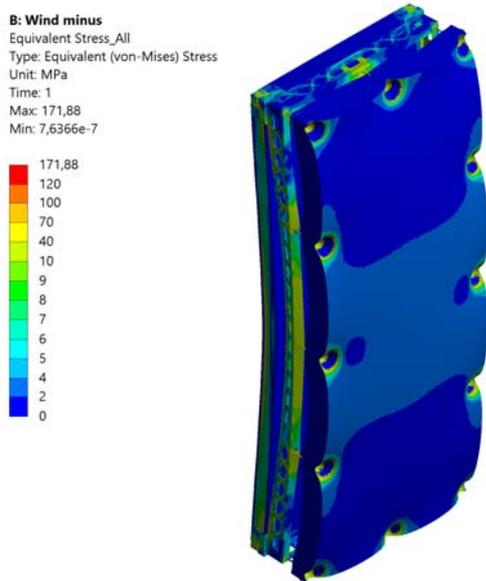
where  $\omega_0$  – normative value of wind pressure,  $z_e$ – equivalent height (m),  $\kappa(z_e)$  и  $\zeta(z_e)$  – coefficients,  $c_{p,+(-)}$ – peak values of aerodynamic coefficients,  $v_{+(-)}$ – wind load correlation coefficients. Normative values of peak wind load are accepted:

$$\omega_+ = 0,460 kPa, \omega_- = -0,841 kPa, \tag{3}$$

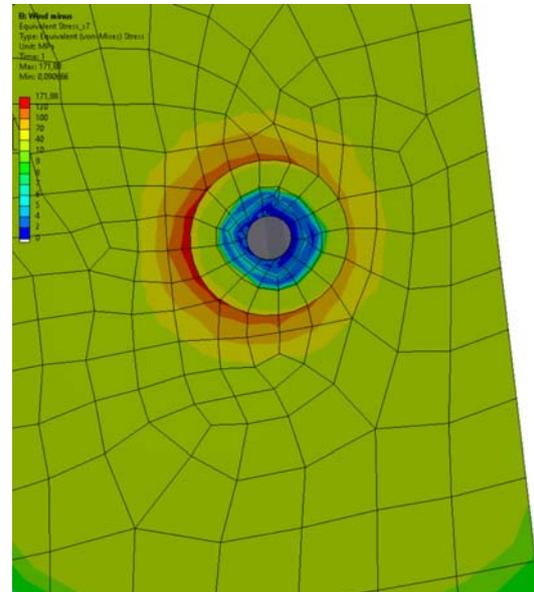
The normative value of horizontal loads on fences for public buildings is 0.8 kN/m.

Limit displacements  $f_u$  of walls made of panels within one floor of multi-storey buildings with flexible fastening of the panel to the building frame is less than  $h_s/300$ , where  $h_s$  is the floor height equal to the panel height. The maximum displacements and stresses in the panel are obtained for the combination of loads with negative effects of wind load  $\omega_-$ . Figure 3 shows the distribution of stresses in panel structure for this load combination case. The zones of maximum stress concentration are located in the outer aluminum layer at the singularity points around the self-tapping shims (171.88 MPa). The maximum stresses in aluminum sheets arise due to the simplification of the model in some

nodes, while the average stresses in the elements do not exceed 120 MPa, which are less than the yield strength of the aluminum alloy (Figure 4).

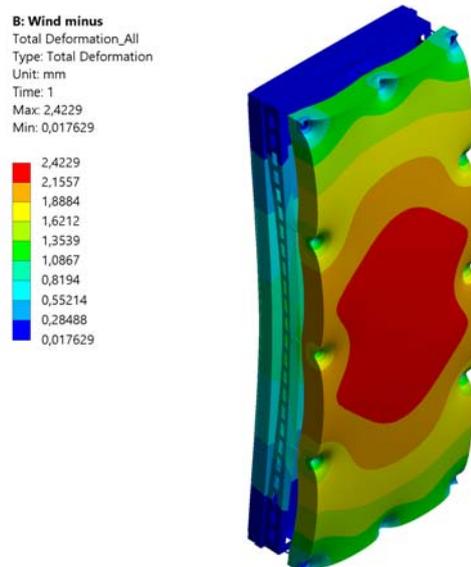


**Figure 3.** The distribution of stresses in MFP.



**Figure 4.** Distribution of stresses near the self-tapping shim in the outer aluminium sheet.

Figure 5 shows the deformations in the panel, the largest displacements occur in the sandwich panel (2.42 mm), which is less than the limiting displacements - 10 mm.



**Figure 5.** Deformations in MFP.

**4. Conclusions**

Test iterative calculation was carried out to determine the required number of fasteners and the diameter of the shims. The calculation established the required number and location of screws. The

further calculation showed that the MFP structure with preassigned materials and thickness of all layers meets the strength and deformation requirements.

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