

Impact of "wet conservation" of mining enterprises on constructing buildings of lightweight materials

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Abstract. The analysis of the influence of flooding of the developed areas of closed mining enterprises on the mechanical characteristics of clay rocks is given. The deformation characteristics of clay shale under prolonged moistening conditions have been experimentally established and proved. Simulation of stress-strain state of soil massifs and building structures by method of finite elements is considered and the influence of power of developed spaces on settlement of building foundations of buildings of light materials is established. The distribution of vertical displacements in the rock massif is presented, the graphs of the dependence of the foundation settlement on the excavation power are plotted, the excess of the standard values of settlement is noted when buildings are located directly above the preparing workings.

1 Introduction

The frame multi-storied buildings occupy the great number of housing construction. However, low-rise housing construction is very popular in nowadays. Due to the modern conditions of increased competition levels and high requirements for the thermal efficiency of facilities, it becomes necessary to use new materials. In terms of reducing heat loss and building enclosing structures costs, cellular materials such as foam and aerated concrete are of great significance.

Having excellent performance characteristics, cellular materials are widely used in the construction of cottages and other low-rise buildings, in Europe and in this country. In this region, after taking into account stricter requirements for thermal insulation of different buildings, these materials are also widely used in large volumes.

Due to the long-term intensive technogenic impacts on the mountain massifs caused by the underground coal mining, the Eastern Donbass is one of the most problematic regions in Russia from an environmental point of view, since the mining of minerals is accompanied by the destruction of rocks over a huge area and, accordingly [1], by the formation of voids. In

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this case, there is a great possibility of deformation of the ground daily surface and the foundations [2, 3]. Therefore, the use of lightweight materials with low strength characteristics requires a sound justification.

2 Justification of the research relevance

The peculiarity of the building construction on the town territory of Shakhty is explained by the fact that over the past century more than 20 mines worked in the mine fields of five coal seams located at different depths [4]. This led to the destruction of the rock and the formation of multi-tiered voids at the depth of several hundred meters.

Designing the technology for mining coal seams and technical measures during the construction of buildings on the surface of the ground made it possible to eliminate the occurrence of the emergencies during the operation of mining enterprises.

During mines operation about 3 m³ of groundwater volume was usually pumped per 1 ton of coal out of the workings to the ground surface. During the period of mine closures in the 90s of the last century and the conservation of mines was done by means of a "wet" method, when the huge underground spaces were flooded with underground water. Moreover, due to the rock destructions in the mountain ranges, the layers were flooded with water even in those places where usually underground water stopped. As a rule, these layers were consisted of clay shales, dense rocks, but weak and prone to soaking.

Under the pressure of the overlying rocks and changes in their physical and mechanical properties with the time, the destruction occurs at the contacts of the blocks and in the massif compaction. Tectonic movements, moistening of new shale surfaces and further massif compaction, accompany this. Since the duration of these processes depends on many factors, like the deformations in the massif and, accordingly, the displacement of the ground surface areas, they can differ significantly, causing uneven settlement of the foundation bases.

A very important factor is the initial size of the worked-out area. Moreover, if the capacity of the recoverable mineral resource did not exceed one meter, then the workings for transporting coal, located every 150-250 m along the strike of the seam, could be more than three meters high. To prevent the destruction of these workings during operation, they were fastened with various materials and security structures were installed (coal pillars, rubble strips of rock, concrete pedestals, and others).

The all above factors cause different values of rock displacements in different areas of the mine fields, which leads to uneven deformations of the foundation bases of both existing and under construction buildings [5, 6]. Therefore, the use of cellular materials even in low-rise buildings especially in the conditions of stress concentration with uneven base resistance o requires detailed studies of the stress distribution in lightweight structures and foundations.

3 Methods and materials

One of the most important factors determining the stable state of underground and surface objects is the rocks displacement. Since mining operations on the territory of the town were mostly completed at the end of the last century, the geomechanical processes had to be stabilized. However, the flooding of underground spaces and the changes in the mechanical properties of rocks, provoked a change in the stress-strain state of the rock massifs (SSS) In this case, the construction of new facilities and, accordingly, the additional load, with an unfavorable combination of factors, can lead to uneven settlement and destruction of building structures.

Rock displacements can be determined by a variety of factors, so it is extremely difficult to predict the areas with the greatest displacements on the ground surface by using analytical

methods at the depth of the workings. In this regard, to study the distribution of stresses in the elements of objects and assess their reliability, it is advisable to use simulation by means of the finite element method (FEM) [7, 8], which is currently used in many software systems.

Simulation is advisable to perform for the most unfavorable case, that is, when the center of the building is located above the preparatory workings. In relation to ribbon foundations, which are used in the construction of buildings in our town, simulation is possible in a flat formulation of the problem.

When assessing the stress-strain state (SSS) of a rock massif, it is necessary to take into account the changes in the strength characteristics of clay shale after flooding of mine workings. For the most objective accounting of changes in the properties of moistened rocks, the method for determining the crushability of crushed stone according to GOST 8269.0-97 was used, by testing crushed clay shale fraction 10 - 20 mm, in a dry and water-saturated state.

The calculations were performed by means of using the Plaxis program. The dimensions of the model within the studied zone are taken from the condition of stabilization of stresses to the values of hydrostatic rock pressure.

The Coulomb-Mohr model was used as a model of the behavior of the soil environment, since this model allows considering it as a first-order approximation in relation to the real soil behavior [9] and this model is the most widespread in modern engineering practice.

Regulatory documents allow using lightweight materials as load-bearing structures in buildings of up to three floors. Therefore, three-storied buildings made of structural foam concrete with a density of 1000 kg/m³, with walls 0.4 m thick, are used for simulation. In order to reduce the model, the load from the two upper floors is applied to the first floor as evenly distributed of the corresponding sizes. This will allow you to model buildings with different spatial planning solutions with minimal time.

4 Discussion of the results

The purpose of the simulation is to identify the nature of the distribution of stresses and displacements in the soil massif [10], as well as the operation of foam concrete structures in the presence or absence of a mine. To calculate the deformations and stresses of these structures, a geometric model of a building made of foam concrete was constructed using the Plaxis software package.

The properties of the destroyed rocks filling the developed space are accepted in accordance with the results of determining the deformation modulus of water-saturated clay shales, since they form the direct roof in most coal seams of the region.

The height of the foundation and the walls of the building are taken based on the most commonly used dimensions in our town.

Since the stability and reliability of buildings on the ground surface is mainly determined by the state of the soil base of the foundation, we consider a soil massif of 50 m deep and 80 m wide. The lower edge of the model is fixed in two planes, and the lateral ones in the horizontal direction (Fig. 1). The mechanical characteristics of the soil mass are taken as averaged for the territory of our town.

Experimental studies of the fractionability of water-saturated clay shale allowed us to establish that at an average depth of the destroyed rocks of 400 m, at stresses close to the vertical rock pressure of 10 MPa, the relative deformations reach 0,447. When the thickness

of the spent layers is 0.8-1.4 m and the minimum height of the preparatory workings is 2.0 m, the following values: 0.5, 0.75, and 1.0 m are used for simulating thickness of the rocks.

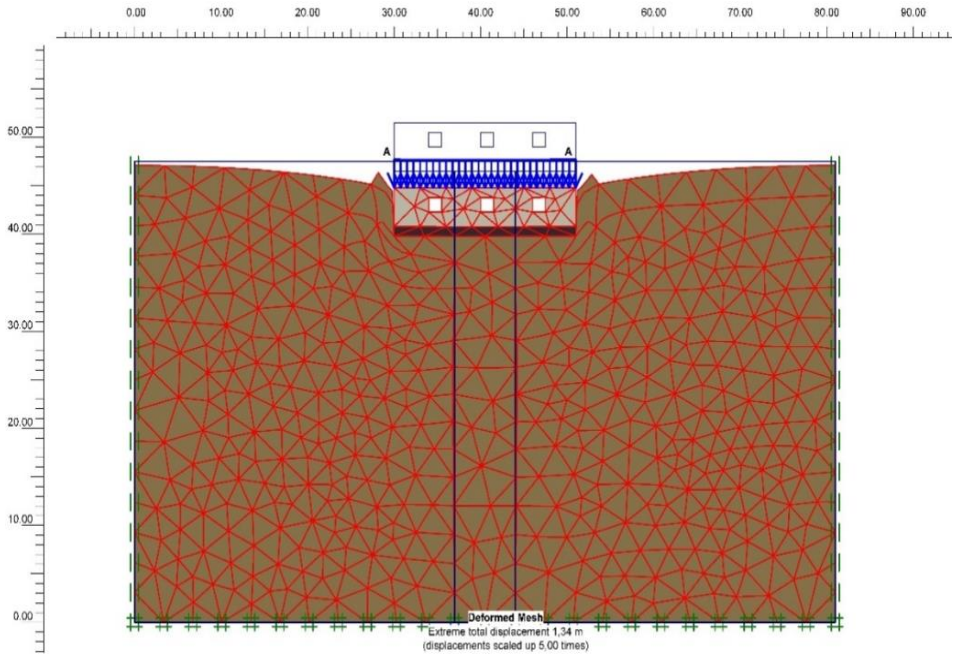


Fig. 1. Vertical movements of the foundation base without additional work

The influence of deformable worked-out spaces can be estimated by the value of the maximum displacements on models without working-out and with worked-out spaces (Fig. 2).

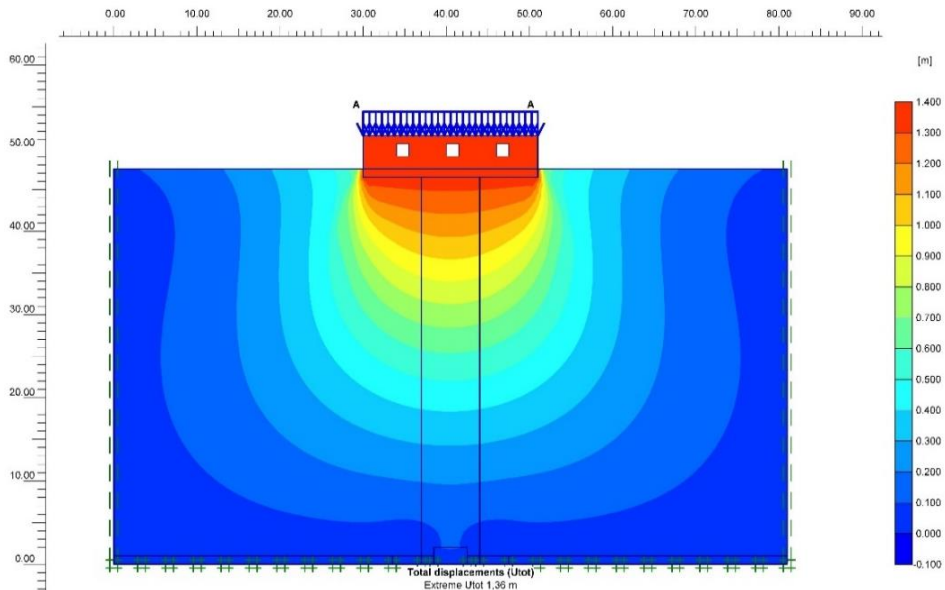


Fig. 2. Isofield of vertical movements of the foundation base at the developed space.

As a result of calculating the models, the isofields of vertical displacements were obtained. The analysis shows that the additional load from the building is accompanied by deformations of 0.079 m, that is, less than the standard for this type of object.

The presence of a deformable layer of 0.5 m leads to an increase in displacements by 1.65, and by 1.0 m by 2.56 times and reaches 0.202 m, which exceeds the permissible values according to SP 22.13330.2016. (SP - set of rules) Also, according to the data obtained, a sample of the displacements of the base of the building foundation with foam concrete walls was made, deformation graphs were constructed as the basis of it (Fig. 3).

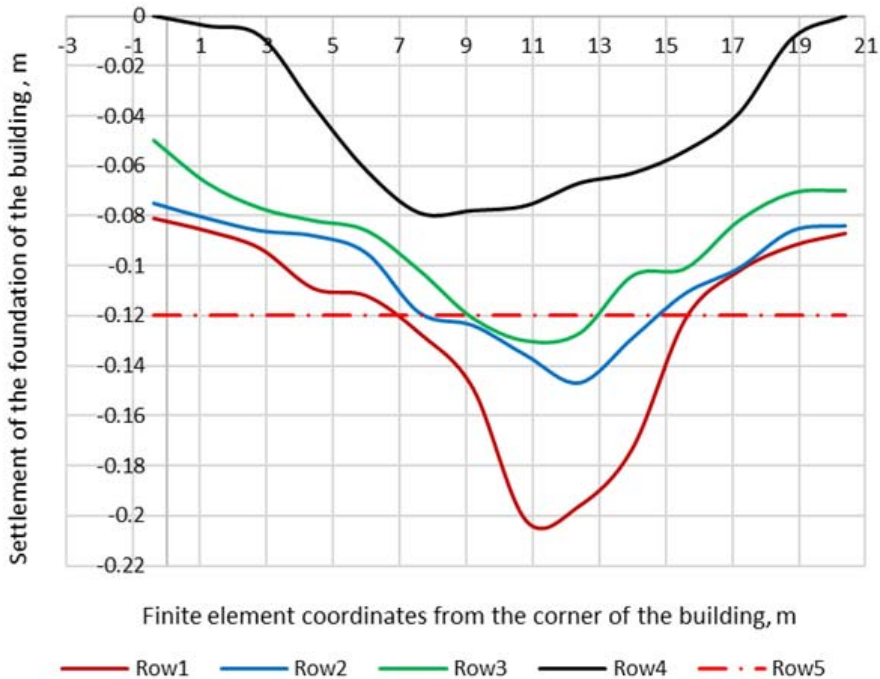


Fig. 3. Settlement of the foundation of the building at different capacities of the developed space: row 1 - 1.00 m; row 2 - 0.75 m; row 3 - 0.50 m; row 4 - without working out; 5 - permissible draft.

5 Conclusion

The carried out study shows that the location of the object under construction above the main workings leads to foundation settlement exceeding the permissible joint venture (0.12 m), even with a conditional deformable layer height of 0.5 m, which requires the use of special structural elements to strengthen the foundations of buildings.

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